CATF CSTEP

Fuel Mix Strategies

for Decarbonising India's Road Transport Sector

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Center for Study of Science, Technology and Policy (CSTEP)
Clean Air Task Force (CATF)
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Generative AI declaration

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Contributors

CSTEP: Spurthi Ravuri, Thirumalai NC
CATF: Gopalakrishnan Duleep, Jonathan Lewis

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Editor: Shayantani C

Designer: Bhawna Welturkar

Bengaluru

No. 18, 10th Cross, Mayura Street

Papanna Layout, Nagashettyhalli

RMV Stage 2, Bengaluru 560094

Karnataka (India)

Noida

1st Floor, Tower-A

Smartworks Corporate Park

Sector 125, Noida 201303

Uttar Pradesh (India)

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Executive Summary

The rapid growth of vehicular traffic in India has significantly impacted greenhouse gas (GHG) emissions, air pollution, and fossil fuel consumption, emphasising the need for aggressive decarbonisation of road transport to support climate action and reduce energy dependence. India aims to achieve 30% electric vehicle (EV) sales by 2030 (EV30@30), but as of 2023–2024, EV adoption stands at only 6%, primarily driven by two-wheelers (2Ws) and three-wheelers (3Ws).Government initiatives such as Faster Adoption and Manufacturing of (Hybrids and) EVs in India schemes I and II and the Electric Mobility Promotion Scheme aim to accelerate EV adoption. However, meeting the 30% target remains challenging, and achieving it is projected to reduce GHG emissions by only 4% by 2030 compared with a low-adoption scenario (~5% sales share).

This report explores strategies such as higher penetration of EVs and hybrid EVs (HEVs) complemented by stricter fuel efficiency norms, assessing their potential to deliver greater emission reductions beyond the EV30@30 commitment. The vehicle stock in the country is projected to 2030 and 2035, resulting in a vehicle stock of 425 and 500 million vehicles by 2035, under the conservative and moderate vehicle growth scenarios, respectively. As a result, the 75 million more vehicles in the moderate growth scenario than in the conservative growth scenario will lead to 13% higher emissions, emphasising the need to control vehicular growth by strengthening public transport systems.

Further, three fuel mix scenarios were considered: (a) the reference scenario, wherein the EV30@30 commitment is fulfilled; (b) the aggressive EV adoption (EV+) scenario, wherein EV penetration is accelerated to reach 50% of the total vehicle sales by 2030 and 75% by 2035; and (c) the aggressive hybrid adoption with fuel efficiency (HEV+/FE) scenario, wherein the sales of HEVs are promoted for the four-wheeler, bus, light goods vehicle (LGV), and medium- and heavy-duty goods vehicle (MHGV) categories, instead of EVs. The fuel efficiencies of internal combustion engine vehicles in the HEV+/FE scenario are also improved annually by 2%–2.5%.

The EV+ scenario will lead to significant fuel savings, especially in the personal vehicle category (2Ws and private cars). With 53% more personal EVs in the stock than in the reference scenario, the EV+ scenario will lead to 13.5% less petrol consumption. In the commercial vehicle segment (3Ws, cabs, buses, LGVs, and MHGVs), this scenario can result in an 8% reduction in diesel demand than that in the reference scenario. However, fuel efficiency improvements under the HEV+/FE scenario can lead to a further decrease of 3% in the diesel consumption of commercial vehicles.

The HEV+/FE scenario can significantly impact road transport emissions by resulting in a 5% higher reduction than that in the reference scenario. This reflects the impact of improved fuel efficiencies and reduced use of high-carbon-intensive electricity (477 gCO_2eq/kWh by 2030). This trend is driven by the high vehicle utilisation in the commercial segment. However, in the personal vehicle segment, the EV+ scenario will become increasingly better than the HEV+/FE scenario by 2033 as the share of renewable energy in electricity generation increases.

Key Insights

Increased personal vehicle sales are detrimental to achieving climate goals and energy independence.

A mix of EVs and HEVs, along with fuel efficiency improvement measures for ICE vehicles, is required for the sustainable and cost-effective decarbonisation of the transport sector.

Grid decarbonisation is key to achieving emission benefits from aggressive EV adoption.

Fuel efficiency norms play a crucial role in decarbonising the road transport sector.

EVs are key to reducing petrol consumption in the personal vehicle category.

Contents

Abbreviations

2W	Two-wheeler
3W	Three-wheeler
4W	Four-wheeler
AVKT	Annual vehicle kilometres travelled
CAFÉ	Corporate average fuel efficiency
CNG	Compressed natural gas
E20	20% Ethanol blended in petrol
EVs	Electric vehicles
FAME	Faster Adoption and Manufacturing of (Hybrids and) EVs in India
FCEV	Fuel-cell electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
ICE	Internal combustion engine
LGV	Light goods vehicle
LNG	Liquefied natural gas
MHGV	Medium- and heavy-duty goods vehicle
MMT	Million metric tonne
Mt CO_2eq	Million tonne of carbon dioxide equivalent
ppl	People
RE	Renewable energy
veh	Vehicle
y-o-y	Year-over-year

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1. Need for Aggressive Decarbonisation

The transport network serves as a lifeline to an economy, bringing its people and goods together for work, education, and trade. In India, about 90% of the passenger traffic and 70% of the freight traffic are carried by the road network (TERI, 2020). Spanning over 6 million kilometres, the Indian road network is the second largest in the world (Ministry of Road Transport and Highways, Government of India, 2023a), serving a population of 1.4 billion and significantly contributing to India's economic growth. In the last decade (2011–2020), India's population grew by 25% (United Nations, Department of Economic and Social Affairs, Population Division, 2022) and its economy improved (represented by gross domestic product [GDP] per capita) by 40% (Ministry of Statistics and Programme Implementation, Government of India, 2022). In the same period, vehicle sales grew by 130% (Ministry of Road Transport and Highways, Government of India, 2023a, 2023c). This rapid vehicular growth had significant impacts on greenhouse gas (GHG) emissions, air quality, and fossil-fuel consumption, in addition to straining road and land infrastructure. Although the road transport sector contributes to only about 9% of the net emissions of the entire economy, it grew by 47% between 2011 and 2020 (Jain & Rankavat, 2023). Petrol and diesel consumption also significantly increased by 87% and 12%, respectively, during this period (Petroleum Planning and Analysis Cell, 2024). These growth trajectories highlight the need to decarbonise the road transport sector in the long term to support India's actions against climate change and energy dependence. For more details about the current growth and consumption patterns of the transport sector in India, refer to Appendix A.

To decarbonise the road transport sector, India is committed to achieving 30% of vehicle sales from electric vehicles (EVs) by 2030 (EV30@30). Given that the share of EVs in the total vehicle sales was only about 5% in FY22, this commitment is practically ambitious. Towards this, the government has spent at least INR 11,000 crore for schemes, such as Faster Adoption and Manufacturing of (Hybrids and) EVs in India (FAME) schemes I and II and Electric Mobility Promotion Scheme, to accelerate the adoption of EVs and plans to increase its spending to achieve the desired scale of adoption. However, this scale of EV adoption is expected to reduce GHG emissions by merely 4% (Abhinav Soman et al., 2020) by 2030, compared with a scenario where the share of EV sales in 2030 is similar to that in 2022 (~5% of sales share). To further reduce emissions from the road transport sector, the Government of India can consider several strategies including higher EV or hybrid EV (HEV) adoption, in addition to implementing stringent fuel efficiency norms.

2. Study Objective and Scope

This study aimed to determine if India would reap significant emission benefits from aggressively adopting EVs or HEVs in the near term (10 years). The report discusses the emission reduction potential of higher penetration of EVs and HEVs in comparison to the reduction from the current commitment of EV30@30.

To assess the impact of the sales of these new vehicle technologies, the vehicle stock in the country was projected to 2030 and 2035 using the Gompertz growth equation (Abhinav Soman et al., 2020), detailed in Appendix B. As per the equation, vehicle ownership is a function of GDP per capita, predefined vehicle saturation levels, and the historical trends in GDP and vehicle ownership. The study considered two different saturation levels: 325 vehicles per 1,000 people (conservative growth scenario) and 400 vehicles per 1,000 people (moderate growth scenario); these saturation levels resulted in a vehicle stock of 425 million and 500 million vehicles by 2035, respectively. The impact of the interventions was determined for these projections.

The common vehicle modes of transport were categorised under personal and commercial applications for the analysis. Two-wheelers (2Ws) and cars were considered personal vehicles, and three-wheelers (3Ws; L5 category[1]), cabs, buses, light goods vehicles (LGVs), and medium- and heavy-duty goods vehicles (MHGVs) were considered commercial vehicles. Cars were differentiated as personal and commercial vehicles as per their utilisation rates or annual vehicle kilometres travelled (AVKT).

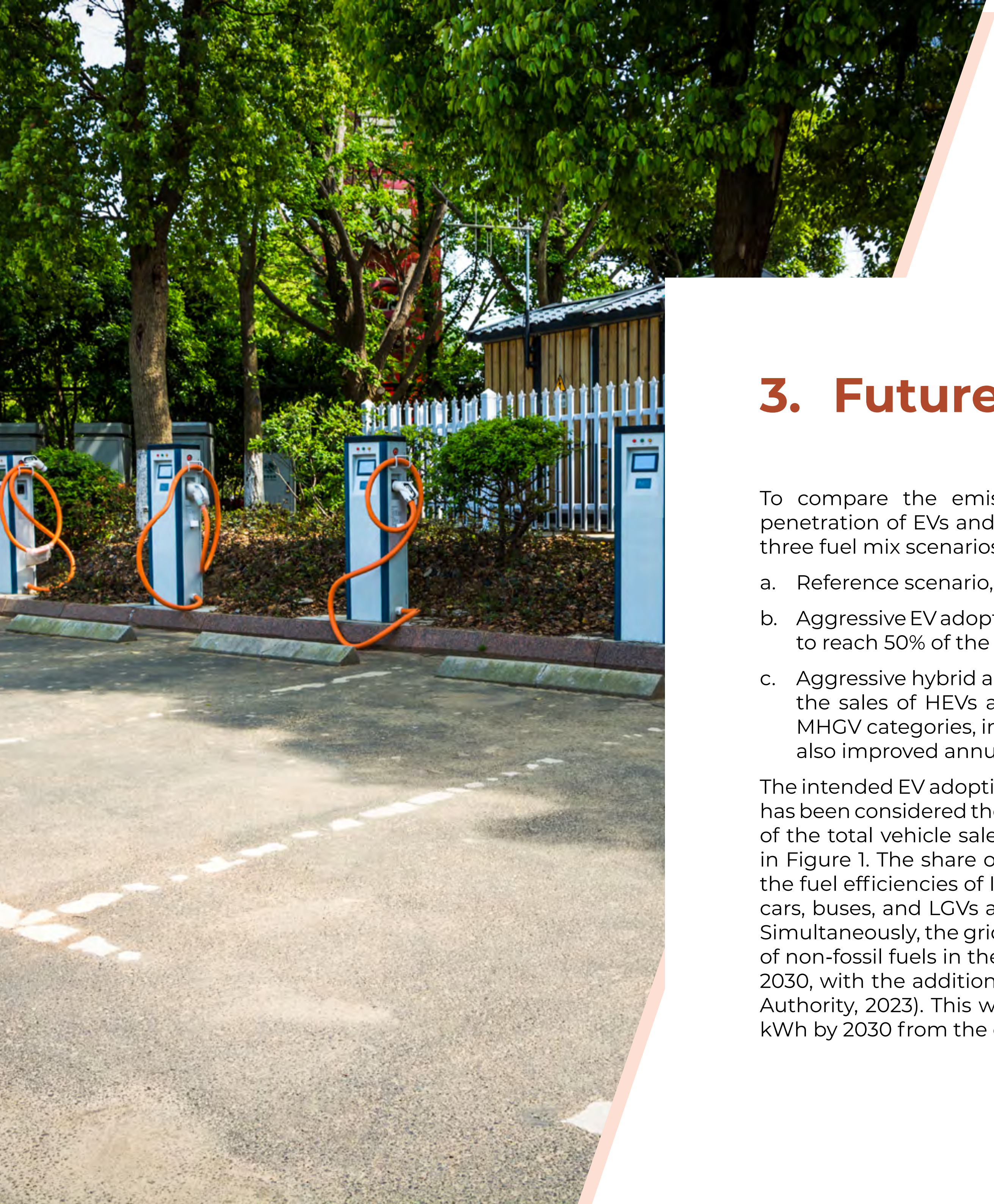
Fuel types considered for this study were diesel, petrol (20% blended with ethanol [E20]), and compressed natural gas (CNG) for internal combustion engines (ICEs); petrol for strong hybrid powertrains[2]; electricity for battery electric powertrains; and green hydrogen (from 100% renewable energy [RE]) for fuel-cell electric vehicles (FCEVs). The fuel efficiencies and utilisation rates used as inputs in the study were collated from the available secondary data for representative vehicles and fuel types and were not recorded from real-world operations. These inputs are listed under Appendix C.

Lately, other fuel types such as liquefied natural gas (LNG), biodiesel, and hydrogen for ICEs are being developed as alternative fuels for commercial vehicles. Of note, this study did not consider their significant adoption levels in the suite of fuel options that could impact the course of decarbonising the road transport sector, on account of their low technology and market-readiness levels.

The study compared the alternative scenarios based on emission reduction and fuel-saving potential, along with the need for government spending; however, their impact on resource adequacy and supply chain dependence was beyond the scope of the current work.

1 L5 category 3Ws are three-wheeled motor vehicles with a maximum speed exceeding 25 kmph and motor power exceeding 0.25 kW

2 Based on the models currently available in the market and announcements made, only strong hybrids have been considered HEVs or hybrid powertrains in the study.



3. Future Fuel Mix Scenarios

To compare the emission reduction and fuel-saving potential of higher penetration of EVs and HEVs to that of the current commitment of EV30@30, three fuel mix scenarios were considered:

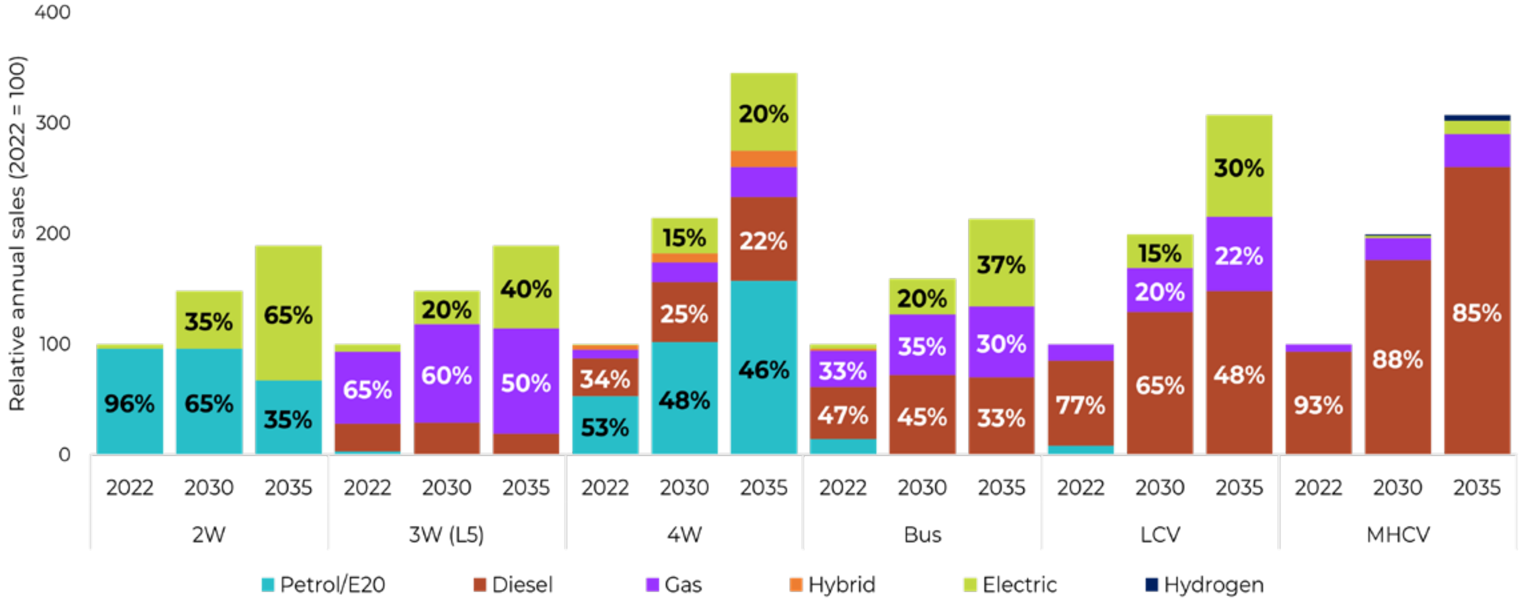
a. Reference scenario, wherein the EV30@30 commitment is fulfilled;

b. Aggressive EV adoption (EV+) scenario, wherein EV penetration is accelerated to reach 50% of the total vehicle sales by 2030 and 75% by 2035; and

c. Aggressive hybrid adoption with fuel efficiency (HEV+/FE) scenario, wherein the sales of HEVs are promoted for the four-wheeler (4W), bus, LGV, and MHGV categories, instead of EVs, and the fuel efficiencies of ICE vehicles are also improved annually by 2%–2.5%.

The intended EV adoption scenario where the EV30@30 commitment is fulfilled has been considered the **reference scenario**. In this scenario, EVs constitute 30% of the total vehicle sales in 2030, followed by petrol, diesel, and gas, as shown in Figure 1. The share of EVs further increases to 50% by 2035. In this scenario, the fuel efficiencies of ICE vehicles are improved annually by 1.4% for 2Ws, 3Ws, cars, buses, and LGVs and 1.1% for MHGVs (International Energy Agency, 2023). Simultaneously, the grid is also expected to decarbonise by increasing the share of non-fossil fuels in the installed capacity from 40% to 64% between 2022 and 2030, with the addition of about 335 GW (Ministry of Power, Central Electricity Authority, 2023). This will result in a lower grid emission factor of 477 gCO_2eq/kWh by 2030 from the current 713 gCO_2eq/kWh.

Figure 1: Fuel share in annual sales under the reference scenario



In the **aggressive EV adoption (EV+) scenario**, EV penetration is accelerated by contributing to 50% of total vehicle sales by 2030 and 75% by 2035 (Figure 2). The sales share of vehicles driven by conventional fuels (petrol, diesel, and CNG) is reduced. The fuel efficiencies of ICE vehicles, in this scenario too, are improved annually by 1.1%–1.4%. The grid is also expected to decarbonise at the rate considered under the reference scenario.

Under **aggressive EV adoption with low RE sources (EV+/LRES)**, EV sales grow at the same pace as the EV+ scenario. However, the grid is not decarbonised as expected by 2030, and the current carbon intensity of 712 gCO_2eq/kWh remains till 2035.

In the **aggressive hybrid adoption with fuel efficiency (HEV+/FE)** scenario, the sales of HEVs are promoted for the 4W, bus, LGV, and MHGV categories, instead of EVs. In this scenario, HEVs contribute to about 30% of the annual sales by 2030 in the 4W and heavier categories (Figure 3). The share of ICE vehicles in this scenario is similar to that in the EV+ scenario, indicating that the two scenarios differ only in the redistribution of sales between EVs and HEVs. The fuel efficiencies of ICE vehicles in this scenario improve annually by 2%–2.5% (International Energy Agency, 2023).

The descriptions of the scenarios are summarised in Table 1.

Table 1: Summary of scenarios considered

	Reference scenario	EV+ scenario	HEV+/FE scenario
Vehicle types and fuel mixes			
Powertrains in 2030 (in the order of sales share)	ICE-petrol, EV, ICE-diesel, ICE-gas, and HEV-petrol	EV, ICE-petrol, ICE-diesel, ICE-gas, and HEV-petrol	ICE-petrol, EV, HEV-petrol, ICE-diesel, and ICE-gas
Share of EVs in new sales in 2030 (author's assumptions)			
2W	35%	55%	55%
3W (L5)	20%	45%	45%
4W	15%	35%	4%
Bus	20%	40%	20%
LGV	15%	25%	10%
MHGV	1%	10%	7%
Vehicle fuel efficiency			
Annual improvement for ICE vehicles	1.4% (light-duty vehicles) and 1.1% (heavy-duty vehicles) (International Energy Agency, 2023)		2.5% (light-duty vehicles) and 2% (heavy-duty vehicles) (International Energy Agency, 2023)
Grid decarbonisation			
Grid emission factor in 2030	477 gCO_2eq/kWh (64% non-fossil fuel in installed capacity) (Ministry of Power, 2023)		
		712 gCO_2eq/kWh (40% non-fossil fuel in installed capacity) (EV+/LRES)	
Policy levers			
Driving policies	FAME policies extended till 2027 to support the sale of 2 million EVs with the same subsidy structure. Ethanol blending programme achieves 20% blending of ethanol in petrol by 2025. The current corporate average fuel efficiency (CAFÉ) norms are maintained at 113 gCO_2eq/km.	New subsidy scheme to support the sale of 3.8 million EVs, with increased support for 4Ws and commercial vehicles. Ethanol blending programme achieves 20% blending of ethanol in petrol by 2025. The current CAFÉ norms are maintained at 113 gCO_2eq/km.	New subsidy scheme to support the sale of 1.6 million HEVs and 3 million EVs. Ethanol blending programme achieves 20% blending of ethanol in petrol by 2025. CAFÉ norms revised to about 91 gCO_2eq/km.

Figure 2: Fuel share in annual sales under the EV+ scenario

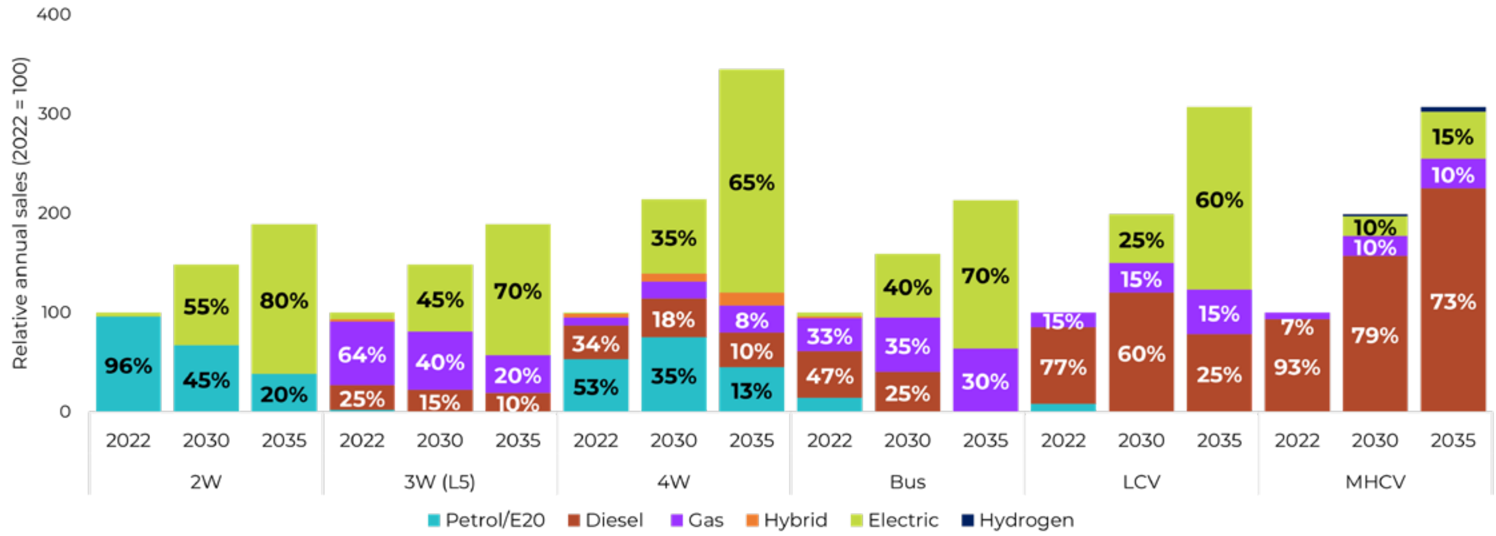
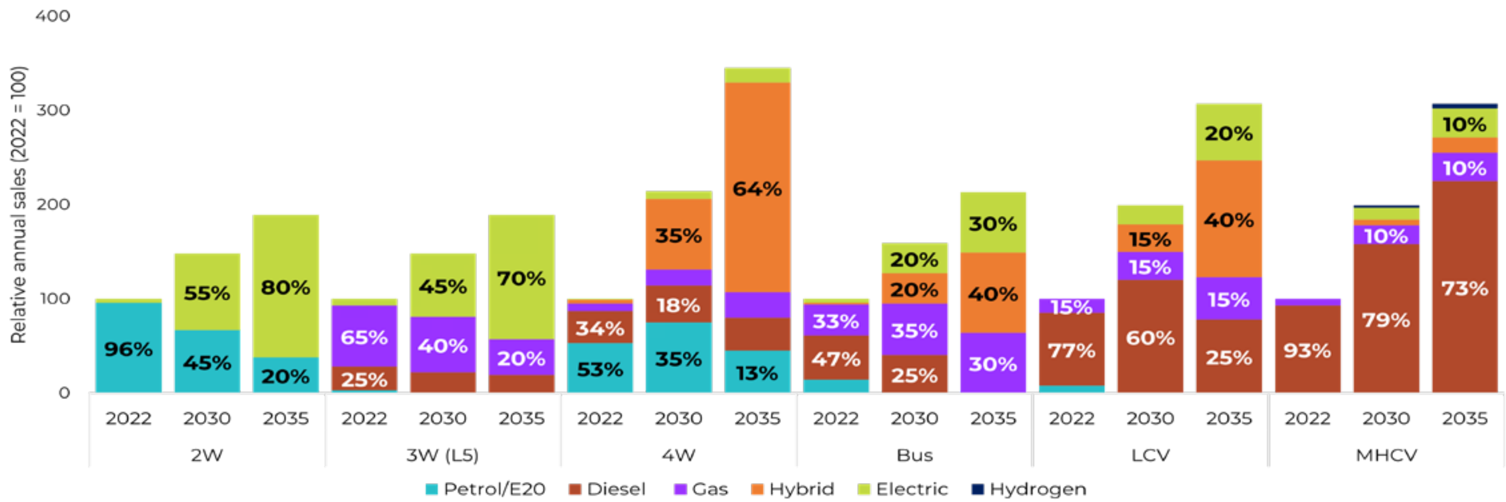


Figure 3: Fuel share in annual sales under the HEV+/FE scenario



4. Findings

The vehicle stock under the conservative and moderate vehicle growth scenarios is expected to grow at a rate of 4.5% and 6%, respectively, till 2035. Consequently, under the reference scenario, the annual petrol and diesel consumption for conservative vehicular growth is expected to increase to 42 million metric tonnes (MMT) and 120 MMT, respectively, in 2030 and 51 MMT and 165 MMT, respectively, by 2035. As a result of this fuel consumption, the annual emissions are expected to increase to ~750 million tonnes of carbon dioxide equivalent (Mt CO_2eq) in 2030 and ~1,020 Mt CO_2eq in 2035. The petrol and diesel consumption under the moderate vehicle growth scenario will be 14% and 9% higher, respectively, in 2035 than that under the conservative scenario, and the resultant emissions in 2035 will be 13% higher than those under the conservative scenario. This highlights the need to limit vehicular sales to achieve emission reduction and fuel independence targets.

Personal and commercial vehicles differ based on their ownership modes, fuel preferences, and utilisation rates and hence are expected to respond differently to fuel-saving and emission-reduction measures under the three scenarios. The relative impacts of the EV+ and HEV+/FE scenarios compared with the reference scenario for the two vehicle categories are discussed below.

4.1. Personal vehicles

Personal vehicles (2Ws and 4Ws) currently constitute 94% (or 210 million) of the active vehicle stock in India (Figure 4) by accounting for about 94% of the new vehicles registered in this decade. This vehicle category contributes to about 30% of the road transport emissions. The personal vehicle stock is expected to grow at an average rate of 5% year-over-year (y-o-y; reaching 400 million vehicles under the conservative growth scenario) and at 7% y-o-y (reaching 475 million vehicles under the moderate growth scenario) by 2035. The impact of the two fuel mix pathways for personal vehicles on fuel consumption and emissions is discussed below.

4.1.1. EV adoption

The personal EV stock, in the reference scenario, grows at an average rate of 40% y-o-y, reaching 37–41 million in 2030 and 126–144 million in 2035. At this growth rate, EVs will account for about 30%-32% of the total personal vehicle stock by 2035. This will result in an annual electricity demand of 40,000–50,500 MU for charging these EVs by 2035.

In 2030, there will be 55% more personal EVs in the EV+ scenario than those in the reference scenario, leading to a 75% higher electricity demand. On the other hand, in the HEV+/FE scenario, by 2030, there will be 38% more EVs than those in the reference scenario (Figure 5), leading to only a 7% higher electricity demand.

Figure 4: Indian vehicle fleet composition in 2022

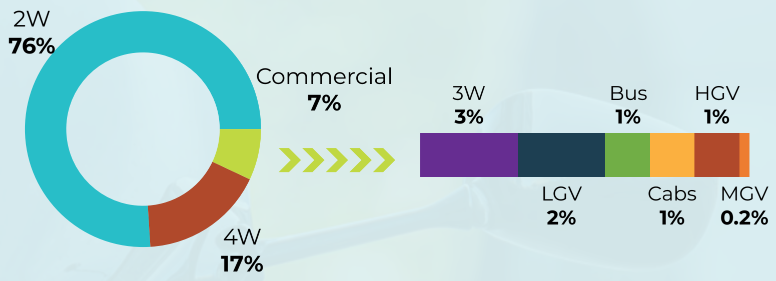
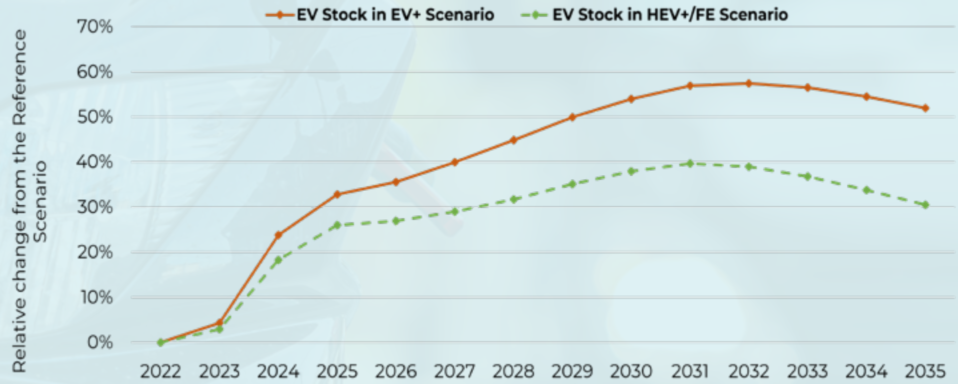


Figure 5: EV stock in the personal vehicle category



By 2035, the sales of EVs in the alternative scenarios (EV+ and HEV+/FE) will reach near saturation at 63%–77% of new personal vehicle sales, whereas those in the reference scenario continue to grow rapidly, reaching only 55%. As a result, the gap in total EV stock between the alternative and reference scenarios begins to narrow. The share of EVs in the total personal vehicle stock will be only 52% (EV+ scenario) and 30% (HEV+/FE scenario) higher than that in the reference scenario by 2035. Further, since the HEV+/FE scenario is characterised by EV adoption in the 2W segment and HEV adoption in the 4W segment, the number of personal EVs will be reduced (by 15% in 2035) than that in the EV+ scenario.

4.1.2. Fuel consumption

As per the vehicle registration data recorded by Vahan (Ministry of Road Transport and Highways, Government of India, n.d.), 99% of the 2Ws and 50% of the 4Ws in the active vehicle stock run on petrol. Hence, the impact of personal EV adoption on petrol consumption was analysed.

The sale of personal petrol vehicles in the reference scenario will peak in 2027, growing at an average of 11% y-o-y. The sales, thereafter, will begin to gradually decline at 6% y-o-y till 2035, when they reach about 38% of the total passenger vehicle sales. This decline can be attributed to the implementation of decarbonisation strategies, such as the increase in EV sales. The resultant annual petrol consumption will increase to reach 40–43 MMT and 50–57 MMT by 2030 and 2035, respectively. By enforcing fuel efficiency norms along with HEV adoption (HEV+/FE scenario) and aggressively promoting EVs (EV+ scenario), petrol consumption in the personal vehicle category will further reduce by 4% and 13.5% by 2035 in the respective scenarios, compared with that in the reference scenario (Figure 6).

In both the EV+ and HEV+/FE scenarios, the sale of petrol vehicles will increase at an average of 12% y-o-y till 2026, followed by a steep decline of 14% y-o-y till 2033 and a plateau thereafter (marked by a 17%–19% share in total personal vehicle sales).

This petrol vehicle sales trend in the EV+ scenario will result in a 13.5% lower petrol consumption than that in the reference scenario by 2035 because of the 52% larger EV stock under this scenario.

In contrast, under the HEV+/FE scenario, the impact of the steep decline in petrol vehicle sales and fuel efficiency improvements will be limited by the rapid increase in the sale of petrol-driven HEVs (about 30 million HEVs will be sold by 2035). The petrol consumption in 2030, hence, will be only 3% lower than that in the reference scenario, and the difference will plateau at nearly 3.7% from 2032 onwards.

Clearly, **the EV+ scenario** (with 52% more EVs in the stock than the reference scenario, resulting in 13.5% less petrol consumption) **is a better pathway for personal vehicles to achieve energy independence.**

4.1.3. GHG emissions

The annual emissions from personal vehicles in the reference scenario will reach 230–253 Mt CO_2eq and 300–355 Mt CO_2eq by 2030 and 2035, respectively. The relative reduction in petrol consumption in both EV+ and HEV+/FE scenarios will result in up to 7.3% lower emissions by 2035 than those in the reference scenario. This reduction is caused by 23% fewer ICE vehicles sold in both scenarios than in the reference scenario and can vary between 0.3% and 7.3% depending on the fuel mix scenario and the degree of grid decarbonisation (Figure 7).

Figure 6: Petrol consumption in the personal vehicle category

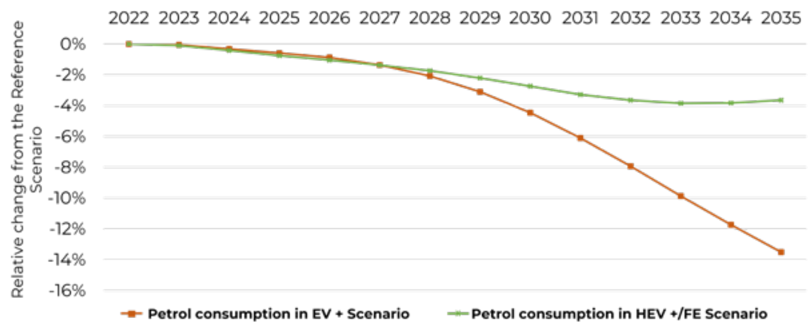
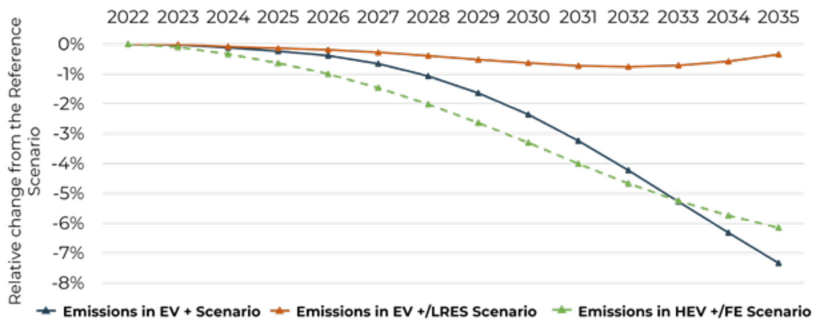


Figure 7: Emissions in the personal vehicle category



In the EV+ scenario, the emission growth will be curbed by the aggressive replacement of ICE vehicles with EVs in the annual vehicle sales. Hence, the emissions will be 2.4% lower in 2030 than those in the reference scenario and will be up to 7.3% lower by 2035. This steep drop is because of the interventions to decarbonise the grid. In the EV+/LRES scenario (wherein the grid does not achieve the desired levels of decarbonisation and continues with the current carbon intensity), the emissions will be at most 0.8% lower (in 2032) than those in the reference scenario, and the advantage diminishes thereafter without grid decarbonisation.

However, in the HEV+/FE scenario, owing to the improved fuel efficiency of ICE vehicles, the emission benefits will steadily increase, yielding 3% lower emissions than those in the reference scenario by 2030 and 6% lower by 2035.

Conclusively, even the EV+/LRES scenario with no improvement in the share of RE sources will have a better emission reduction potential than the reference scenario. However, the HEV+/FE scenario will have a higher emission reduction potential till 2033, after which an aggressive EV adoption will yield higher benefits as the share of RE sources in the grid increases.

4.2. Commercial vehicles

Commercial vehicles (3Ws, cabs, LGVs, and MHGVs) currently constitute 8% of the active vehicle stock in India. In the commercial vehicle fleet, 3Ws that provide micro-transit services for short-distance travel and last-mile goods mobility account for 36% of the share and LGVs used for urban goods movement account for 23%, followed by cabs for urban passenger movement with 13% and MHGVs handling regional and national goods movement with 18% (Figure 4). Together, these vehicle types contribute to 69% of the road transport emissions. The commercial vehicle stock is expected to grow at an average rate of 5% y-o-y (reaching 25 million vehicles under the conservative growth scenario) and at 6% y-o-y (reaching 30 million vehicles under the moderate growth scenario) by 2035. The impact of the two fuel mix pathways for commercial vehicles on fuel consumption and emissions is discussed below.

4.2.1. EV adoption

The commercial EV stock in the reference scenario will grow at an average rate of 40% y-o-y between 2022 and 2030 and at 19% y-o-y till 2035. At this growth rate, there will be 1.4–1.6 million EVs in 2030 and 4.3–5.4 million EVs in 2035. Consequently, by 2035, EVs will account for 25% of the new commercial vehicle sales and about 17%–19% of the total commercial vehicle stock. This will result in an annual electricity demand of 40,700–55,000 MU for charging these EVs by 2035.

By 2030, there will be about 65% more commercial EVs in the EV+ scenario and 35% more in the HEV+/FE scenario than those in the reference scenario (Figure 8). The difference in the EV stock volume follows an S curve, where it begins to plateau (as in the EV+ scenario) or decrease (as in the HEV+/FE scenario) from 2033 onwards. This is because the growth of the EV stock in the EV+ and HEV+/FE scenarios will begin to slow down, upon reaching peak adoption rates (48%–52% in the EV+ scenario and 31%–33% in the HEV+/FE scenario) from 2033 onwards. By 2035, the EV+ scenario will have almost twice as many EVs as the reference scenario and 2.5 times the electricity demand. However, the HEV+/FE scenario will have 40% more EVs than those in the reference scenario and 40% higher electricity demand.

By 2035, the share of EVs in the total commercial vehicle stock would be about 23% and 33% under the HEV+/FE and EV+ scenarios, respectively. This EV stock in the HEV+/FE scenario predominantly comprises 3Ws. No HEV adoption was considered for this segment, given the lack of available 3W HEV models during this study.

4.2.2. Fuel consumption

About 63% of the commercial vehicle stock currently runs on diesel (Ministry of Road Transport and Highways, Government of India, n.d.). The share of diesel-run vehicles is higher (>90%) among freight vehicles (LGVs and MHGVs) than among passenger vehicles. The sale of diesel commercial vehicles in the reference scenario will grow steadily at an average rate of 7% y-o-y till 2035, reaching 46% of total commercial vehicle sales. The resultant annual diesel consumption will increase to reach 110–114 MMT and 150–162 MMT by 2030 and 2035, respectively. The aggressive promotion of EVs and fuel efficiency improvements with HEV adoption will result in 8.5%–12% less diesel consumption annually by 2035 under the EV+ and HEV+/FE scenarios (Figure 9) compared with the reference scenario.

Figure 8: EV stock in the commercial vehicle category

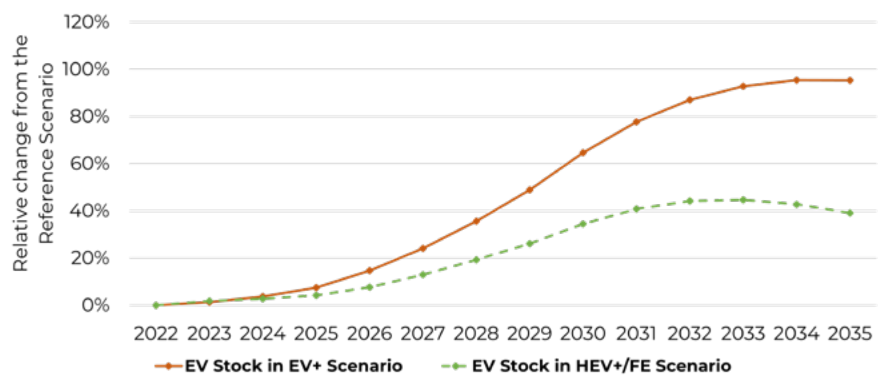
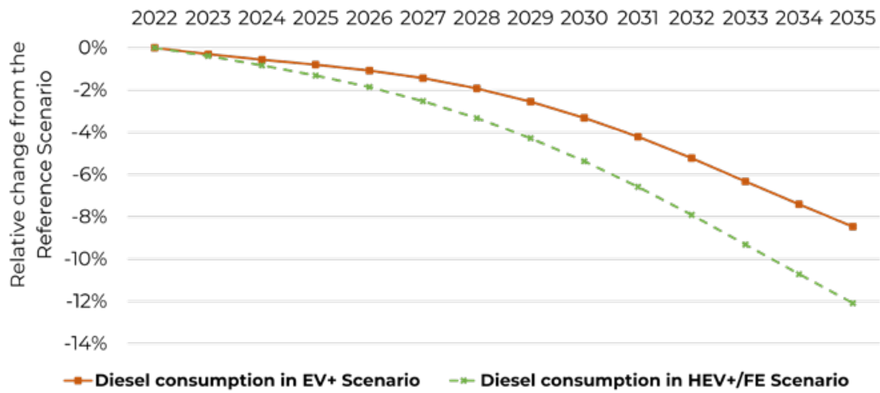


Figure 9: Diesel consumption in the commercial vehicle category



The sale of diesel vehicles in both EV+ and HEV+/FE scenarios will grow at an average rate of 12% y-o-y till 2028, begin to gradually decline at 3% y-o-y till 2033, and tend towards a plateau when the share of diesel commercial vehicles drops to about 32% in 2035.

This trend will result in about 3% lower diesel consumption in 2030 in the EV+ scenario than that in the reference scenario and will drop to about 8.5% lower by 2035.

In the HEV+/FE scenario, fuel efficiency improvements will result in steeper diesel-avoiding potential. In this case, the diesel consumption will be 5% lower in 2030 and 12% lower in 2035 than that in the reference scenario.

It is evident that fuel efficiency improvements are key for fuel savings in case of commercial vehicles. Thus, the HEV+/FE scenario is a better pathway for commercial vehicles to ensure fuel savings.

4.2.3. GHG emissions

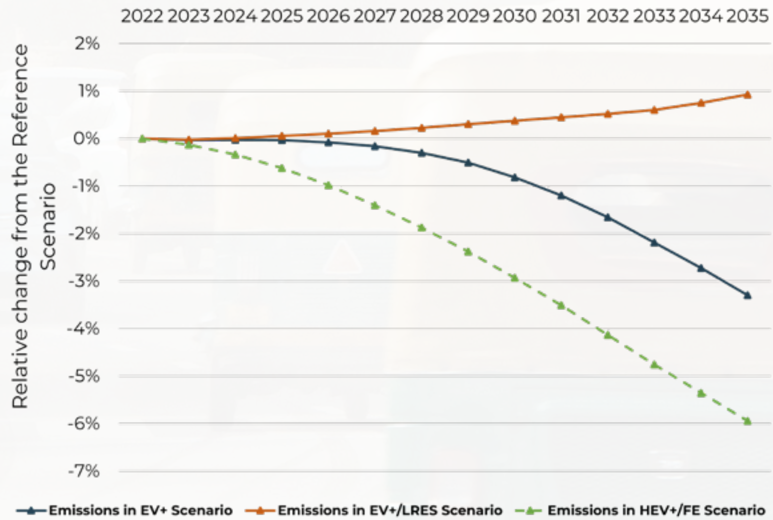
The annual emissions from commercial vehicles in the reference scenario will reach 520–554 Mt CO_2eq and 725–800 Mt CO_2eq by 2030 and 2035, respectively. The relative diesel savings observed in the EV+ and HEV+/FE scenarios will also translate to reduced emissions (3%–6% lower than the reference scenario), given that the grid decarbonisation targets are met (Figure 10).

In the EV+ scenario, wherein the grid decarbonisation targets are achieved, the emission benefits of aggressive commercial EV adoption will not be very significant till 2035 (3.3% lower by 2035 than the reference scenario). This is largely on account of the high energy demand for commercial vehicles met by carbon-intensive electricity. In case of the EV+/LRES scenario, wherein the grid is not decarbonised, the aggressive adoption of EVs will be counterproductive, resulting in slightly higher emissions (by ~1%) by 2035 than those in the reference scenario.

In contrast, the HEV+/FE scenario will yield steep reductions in emissions compared with the reference scenario. The emissions in 2030 and 2035 will be ~3% and ~6% lower, respectively, than those in the reference scenario.

Conclusively, the emission benefits from these interventions can only reduce the emissions from commercial vehicles by an additional 6% from the reference scenario. However, it is evident that the fuel efficiency improvements in the HEV+/FE scenario are crucial for achieving these results. The adoption of EVs in these vehicle segments does not yield benefits unless the grid is aggressively decarbonised.

Figure 10: Emissions in the commercial vehicle category



4.3. Fiscal impact

The purchase cost of EVs and HEVs is one of the major deterrents to the mass adoption of these technologies in India. The Ministry of Heavy Industries launched the FAME scheme in 2015 to provide purchase subsidies for EVs and HEVs. Since its inception, the scheme has allocated over INR 11,000 crore to support the purchase of about 2 million EVs.

However, EVs are still sold at a 10%–30% premium compared to ICE vehicles (Figure 11) owing to the high cost of batteries, EV technology, and the lack of economies of scale for manufacturing. Thus, promoting the scale of EV adoption requires subsidies to continue and more vehicles to be financially supported, necessitating a higher budget allocation for such schemes.

Given the disparities in purchase costs of EVs, it is considered that purchase incentives to the tune of 10%–40% of the ex-showroom cost of EVs (Table 2) would be required to further encourage the purchase of EVs. To support the desired EV adoption rates in the reference scenario, it is proposed that about 5% of the required EV sales in the next 5 years be subsidised. This scale of support would require a budget of INR 10,500 crore. Similarly, for the EV+ scenario, with higher desired EV adoption rates, it is proposed that subsidies be provided to all EV modes till their sales cross the technology adoption chasm when the EV penetration crosses 10% in the 2W and commercial vehicle segments and 20% in the 4W segment. Such subsidies would require a cumulative budget of INR 35,000 crore. For the HEV+/FE scenario, this study proposes that 5%–10% of the required EV sales be subsidised. This scale of support would also require a budget of INR 10,500 crore. The resultant number of EVs to be subsidised for each mode and the required budget for subsidies under the three scenarios are detailed in Table 2.

Figure 11: Cost of EVs with respect to ICE vehicles without subsidies

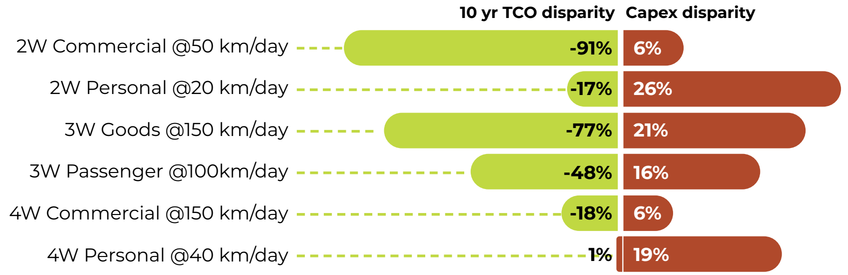


Table 2: Scale of subsidies required under each scenario for conservative vehicle growth

Vehicle modes	Maximum subsidy per vehicle (INR)	Number of EVs subsidised		
		Reference scenario	EV+ scenario	HEV+/FE scenario
e-2W	20,000	15,00,000	24,00,000	24,00,000
e-3W	50,000	4,80,000	5,00,000	5,00,000
e-4W	1,87,500	90,000	11,00,000	-
HEV-4W	1,00,000	-	-	11,00,000
e-LCV	1,87,500	10,000	50,000	15,000
HEV-LCV	1,00,000	-	-	35,000
e-bus	25,00,000	20,000	20,000	7,500
HEV-bus	10,00,000	-	-	12,500
e-MHCV	50,00,000	1,000	2,000	1,000
HEV-MHCV	20,00,000	-	-	1,000
Budget for subsidies		**INR 10,500 crore**	**INR 35,000 crore**	**INR 22,750 crore**

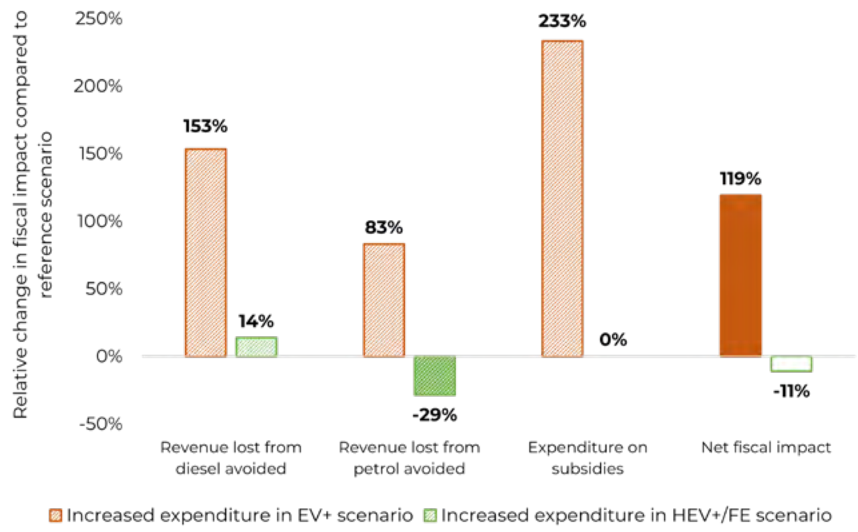
However, the targeted scale of EV and HEV adoption will result in a reduction of fuel consumption and will consequently result in a loss of revenue to the Indian exchequer from the excise duty collected through the sale of petrol and diesel. Under the reference scenario, the sale of 130–145 million EVs between 2023 and 2035 will help avoid the sale of 12–16 MMT of petrol and 10.5–14 MMT of diesel by 2035. Consequently, this will lead to a loss of revenue collected through the sale of these fuels, amounting to INR 1,20,000–1,50,000 crore. The relative fiscal impact of the EV+ and HEV+/FE scenarios compared with the reference scenario is displayed in Figure 12.

In the EV+ scenario, by subsidising 4 million EVs, the government will have to spend ~230% more on subsidies. This is in addition to losing 110% more revenue than that in the reference scenario due to the avoided sale of petrol and diesel on account of 70 million more EVs purchased in this scenario.

In the HEV+/FE scenario, the government can restructure the budget for the reference scenario to subsidise 3 million EVs (primarily in the commercial vehicle segment) while earning about 12% more revenue due to the increased petrol sales for HEVs despite the reduced sale of diesel.

These fiscal implications are crucial in determining the effectiveness of the three scenarios. Conclusively, **the HEV+/FE scenario will be a more cost-effective pathway for India than the EV+ scenario.**

Figure 12: Impact on government budget



5. Key Takeaways

This study investigated the potential benefits of increasing the adoption of EVs and HEVs beyond the current commitment of EV30@30 (30% of the total vehicles sales by 2030). Two alternative scenarios were considered: (a) an aggressive EV adoption (EV+) scenario, wherein EV penetration is accelerated to reach 75% by 2035; and (b) an aggressive hybrid adoption with fuel efficiency (HEV+/FE) scenario, wherein the sales of HEVs are promoted for 4W, bus, LGV, and MHGV categories, along with fuel efficiencies improvement of ICE vehicles. The potential impact of these scenarios on GHG emissions is illustrated in Figure 13.

The following can be inferred from the study:

Increased personal vehicle sales are detrimental to achieving climate goals and energy independence. Controlled vehicle ownership, driven by improved public transport services and an increased share of rail transport in freight movement, is essential for curbing the emission growth.

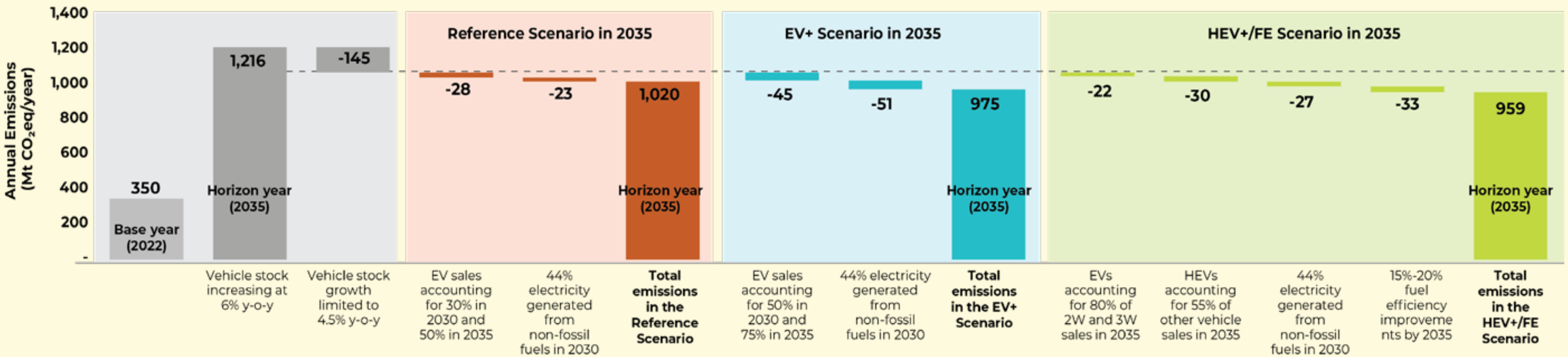
A mix of EVs and HEVs, along with fuel efficiency improvement measures for ICE vehicles, is required for sustainable and cost-effective decarbonisation of the sector. An EV -focussed strategy, as in the EV+ scenario, will not yield significant emission reductions. Especially for commercial vehicles, increasing the share of EVs in the total commercial vehicle sales in 2035 from 25% to 50% will only result in a ~3% reduction in emissions.

Grid decarbonisation is key to achieving emission benefits from aggressive EV adoption. The EV sale-focussed strategy will have a higher emission reduction potential in the personal vehicle category only if the share of non-fossil fuels in the installed capacity increases beyond 64% by 2030. To achieve a significant emission reduction potential in the commercial vehicle category, the share of non-fossil fuels should reach the target earlier than expected.

Fuel efficiency norms play a crucial role in decarbonising the road transport sector. Technological advancements (including hybridisation) that can improve the fuel efficiency of vehicles have the potential to reduce fuel consumption and emissions significantly (by at least 3%).

However, **EVs play a major role in reducing petrol consumption in the personal vehicle category.** About 65 million more personal EVs on road by 2030 in the EV+ scenario will help reduce the consumption of 7 MMT of petrol annually from 2035 onwards.

Figure 13: Emission reduction potential of the mitigation measures



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7. Appendices

Appendix A: India's road transport sector—Status quo

India recorded an average annual sale of 20 million vehicles during 2011–2019 and witnessed a drop in the sale in 2020 due to the COVID-19 pandemic (Figure A1). Since then, the automobile industry has recovered, with 21 million vehicles sold in 2023. Based on these sales and the survival fractions for each vehicle segment, the active vehicle fleet in India was estimated to be around 230 million in 2022.

Within the active vehicle fleet, personal vehicles (two-wheelers [2Ws] and four-wheelers [4Ws]) account for 92% (or 210 million) of the stock (Figure A2). This reflects the growing Indian economy and the increasing purchasing power of its people, who aspire to own personal vehicles as their incomes grow. However, among personal vehicles, 2Ws are more popular in the Indian market, unlike the American and European markets, making the Indian 2W market one of the largest in the world. In 2022, every other Indian household owned a 2W, whereas only 13% of households owned a 4W. This preference can be attributed to the lower purchase and operating costs as well as the greater convenience of manoeuvring through congested urban roads with 2Ws compared with 4Ws.

Figure A1: Historical sales trend in India for (a) personal and all vehicles and (b) commercial vehicles

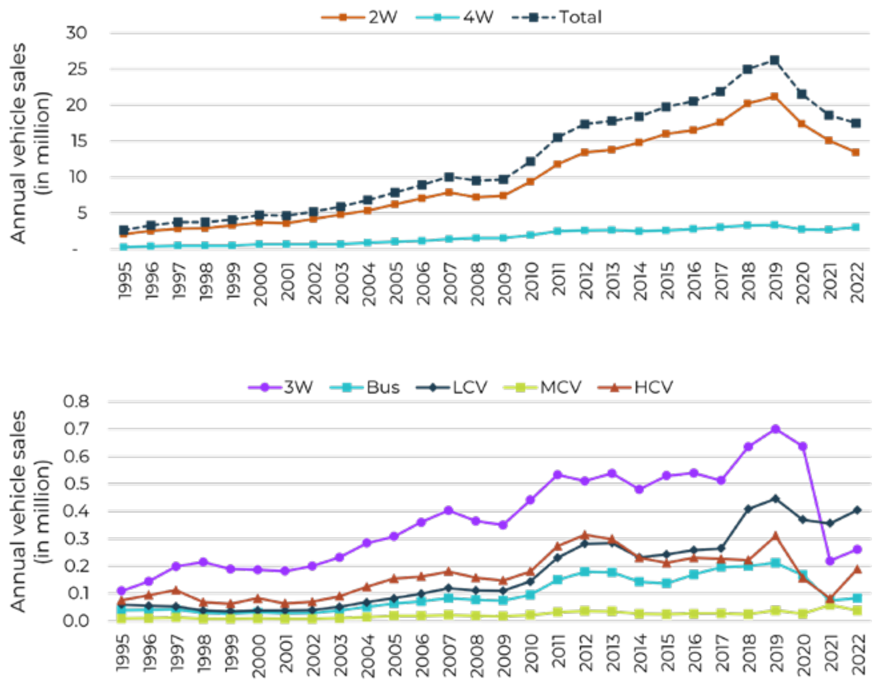
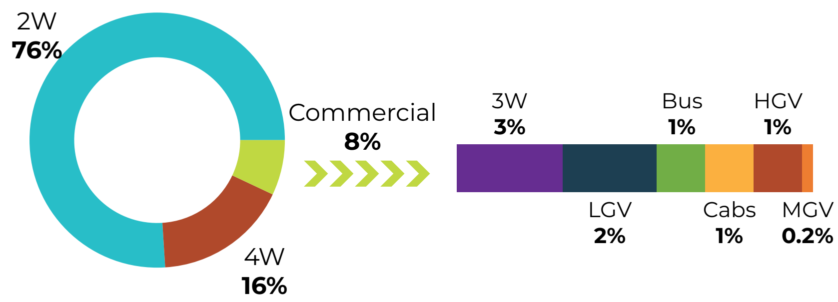


Figure A2: Indian vehicle fleet composition in 2022

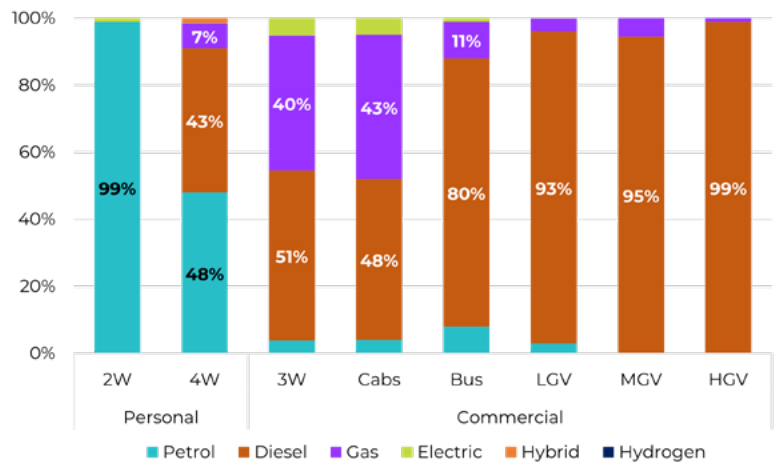


The sales of 3Ws grew from 0.4 million in 2010 to 0.7 million in 2019 (Figure A1) at an average rate of 4% y-o-y. In the commercial vehicle fleet, third-wheelers (3Ws) that provide micro-transit services for short-distance travel and last-mile goods mobility account for 36% (Figure A2). This is followed by light goods vehicles (LGVs) for urban goods movement and cabs for urban passenger movement, with 23% and 13% shares in the commercial fleet (Figure A2). With the increased market for e-commerce and urban logistics, the LGV segment witnessed the highest average growth rate of 12% y-o-y between 2010 and 2019. This trend is only expected to continue along with the e-commerce market. Supporting the LGVs are the medium- and heavy-duty goods vehicles (MHGVs) that handle regional and national goods movement. These vehicles hold an 18% share in the Indian commercial vehicle fleet (Figure A2). In Tier I and Tier II cities, about 33% of trips are made in public transit systems (Dawda et al., 2020). Yet, there are only 0.8 million buses (or 9% share in the commercial vehicle fleet) catering to the 500 million urban population. In cities where public transport is not available or accessible, cabs and 3Ws become the primary mode, along with personal vehicles.

Transport energy sources and fuel mix

About 97% of the Indian vehicle fleet depends on fossil fuels (petrol and diesel) as the primary energy source. In 2022, India produced 29 MMT of crude oil and imported 233 MMT of it. The economy consumed 223 MMT of petroleum products, of which 35 MMT of petrol and 86 MMT of diesel were consumed. Around 99% of the petrol and 94% of the diesel consumed domestically were used by the road transport sector. Petrol is predominantly used by personal vehicles and diesel by commercial vehicles (Figure A3). In 2022, the import dependency based on the consumption of petroleum products stood at 87% (Petroleum Planning and Analysis Cell, 2023). To reduce this import dependence and fossil fuel consumption, the Government of India launched the Ethanol Blending Programme in 2003. This programme was set to achieve 20% blending of ethanol in petrol by 2025 (Petroleum Planning and Analysis Cell, 2023). India achieved the intermediate target of 10% ethanol blending in June 2022, ahead of its target of November 2022 (Ministry of Petroleum & Natural Gas, 2022). By December 2023, 12% blending has been attained. Further, 20% ethanol-blended petrol (E20) is already sold at several public sector oil marketing companies (Petroleum Planning and Analysis Cell, 2023). This programme also has secondary benefits of reducing the environmental impacts of using fossil fuels and providing the farmers an opportunity to double their income. Additionally, the sale of biodiesel (B100) for blending with diesel is being promoted in the transport sector.

Figure A3: Fuel composition of the Indian vehicle fleet in 2022



In addition to biofuels, compressed natural gas (CNG) plays a vital role in the Indian transport sector as a cheaper and cleaner alternative fuel. India's import dependency of liquefied natural gas (LNG), which is a carrier for natural gas that is compressed before distributing for transport and domestic purposes, is about 44% (Ministry of Petroleum & Natural Gas, 2022). It is primarily used in the commercial vehicle segment as a more economical fuel than diesel.

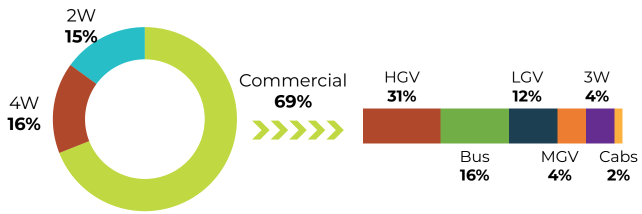
To further decarbonise the transport sector, EVs have gained attention in the last decade. These battery-operated vehicles have no tailpipe emissions and use electricity to charge the on-board battery that powers the motor. However, their high purchase cost and need for a dedicated charging network are major barriers to their large-scale adoption in India. The Government of India has been promoting the adoption of EVs since 2015 through purchase subsidies, production incentives, and charging infrastructure expansion. In 2022, India recorded the sale of over a million EVs, accounting for 4.7% of the total sales. This adoption was mainly driven by the 2W and 3W segments owing to their lower operating costs that negate the high purchase costs. The electricity used to charge these vehicles is primarily (74%) generated using coal and partly (only 12.5%) using renewable energy sources such as solar, wind, biomass, and small hydro (Ministry of Power, 2023). The Indian electricity grid is one of the most carbon-intensive in the world at 0.715 kg CO_2eq/kWh (Ministry of Power, 2023). India is committed to deriving 50% of its installed power capacity from non-fossil-based energy sources by 2030 (Ministry of Environment, Forest and Climate Change, 2023). Achieving this target will bring the emission intensity of the grid to 0.45 kg CO_2eq/kWh by 2030, making EVs a greener alternative to internal combustion engine vehicles (Ministry of Power, 2023).

In continued attempts to decarbonise the sector, the Ministry of Road Transport & Highways has also planned to introduce alternative fuels such as ethanol-blended petrol (E10, E12, E15, and E20), flex fuels (E85 or E100), ethanol-blended diesel (ED95), bio-diesel, bio-CNG, LNG, methanol-blended petrol (M15 or M100), methanol-blended diesel (MD95), dual fuel, M85, and dimethyl ether (D100), hydrogen fuel cells, and hydrogen CNG vehicles (Ministry of Road Transport and Highways, Government of India, 2023b).

Transport emissions

In 2022, the road transport sector was estimated to emit about 350 Mt CO_2eq. This accounts for about 9% of the overall emissions in India. Although commercial vehicles accounted for only 8% of the vehicle stock, they contributed to as much as 70% of the emissions. In contrast, passenger vehicles contributed to only 30% of greenhouse gas emissions (Figure A4). This is mainly because commercial vehicles have higher utilisation in annual kilometres travelled and run predominantly on diesel (Figure A3), which is more carbon-intensive than petrol.

Figure A4: Composition of transport emissions in 2022



Appendix B: Vehicle stock projections

The Gompertz growth function (Abhinav Soman et al., 2020) was employed to project vehicle ownership in India to 2030 and 2035. The function estimates vehicle ownership as a function of the gross domestic product (GDP) per capita, saturation levels, and historical trends (Equation 1). The historical (2001–2020) vehicle ownership and GDP per capita are positively correlated (r = 0.99). The year 2022 was considered the base year for the projections.

$$V_i = \gamma\theta e^{\alpha e^{\beta G_i}} + (1+\theta)V_{i-1}, \quad (1)$$

where

V_i = vehicle ownership in year i (vehicles per 1,000 people);

γ = saturation level of vehicle ownership (vehicles per 1,000 people);

G_i = GDP per capita in year *i*;

α and β = parameters that define the shape of the curve; and

θ = speed of adjustment for vehicle ownership, with respect to GDP growth ($0 < \theta < 1$).

Because the growth rate of 2Ws in the Indian transport sector is likely to follow a separate trajectory, the ownership of 2Ws was modelled separately from the other vehicle types. The assumptions and inputs considered for the model are detailed in Table B1.

Table B1: Inputs and assumptions in the Gompertz model

Parameter	2Ws	Other vehicles	Source
Vehicle ownership in 2022 (veh/1,000 ppl) (Vi)	122	38	Analysis based on survival curve on historical sales data
α	0.375	0.202	Ordinary least squares regression in Eq 1 with historical data
β	-0.287	-0.329	
θ	0.09	0.08	Abhinav Soman et al., 2020

The current and historical GDP values were obtained from the National Accounts Statistics records. GDP was projected using data from the International Monetary Fund database and the India Energy Security Scenarios model. The total vehicle stock for each year is calculated using the estimated ownership values and the projected population from the World Population Prospects (United Nations, Department of Economic and Social Affairs, Population Division, 2022).

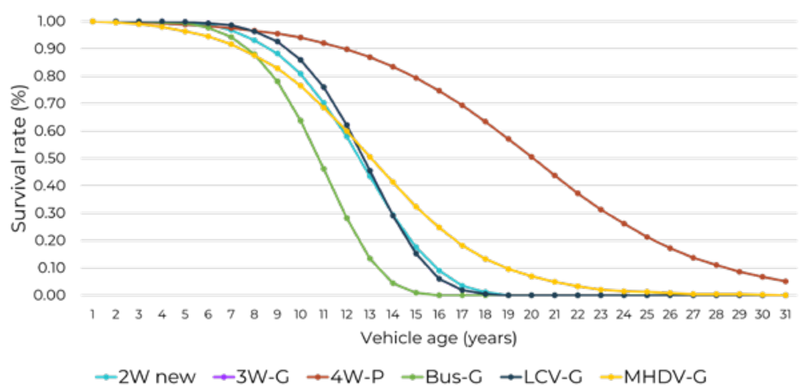
Different values of the saturation level (γ) were used to consider the various levels of vehicle growth in India. The two scenarios considered are as follows:

Conservative vehicular growth: A saturation of 2Ws at 225 veh/1,000 ppl and other vehicles at 100 veh/1,000 ppl (total saturation of 600 veh/1,000 ppl)

Moderate vehicular growth: 2Ws saturated at 250 veh/1,000 ppl and other vehicles at 150 veh/1,000 ppl (overall saturation at 400 veh/1,000 ppl)

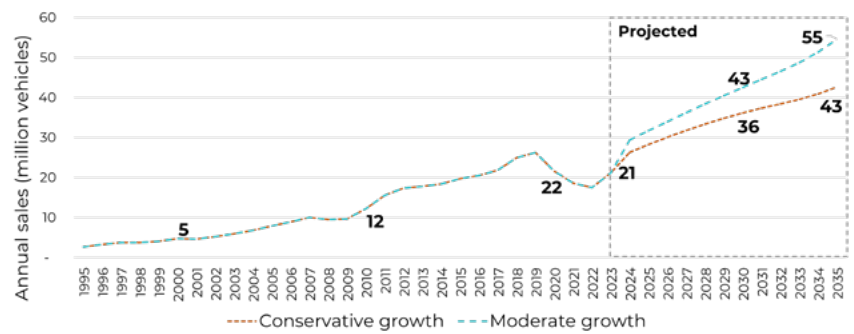
These saturation level constraints resulted in vehicle projections of 430 million and 500 million by 2035 in the conservative and moderate scenarios, respectively. With the projected vehicle stock for each year until 2035, the annual sales were estimated using historical sales data (Society of Indian Automobile Manufacturers, n.d.) and survival factors (Goel & Guttikunda, 2015; Pandey & Venkataraman, 2014). The survival curves for each vehicle type are illustrated in Figure B1.

Figure B1: Mode-wise vehicle survival curves



The resultant projected annual vehicle sales are shown in Figure B2.

Figure B2: Projected annual vehicle sales



Appendix C: Inputs and assumptions

Vehicle stock projection assumptions

Table C1: Assumptions for vehicle stock projection

Factors	2010	2022	2030(p)*	2035(p)
GDP per capita (2012 INR)	57,592	1,11,096	1,67,621	2,20,197
Population (billion)	1.25	1.42	1.52	1.57
2W ownership (2W/1,000 people)	51	122	177–190	195–212
Other vehicle ownership (veh/1,000 people)	20	38	67–89	78–110
Vehicle population (million)	90	227	370–423	430–500
Modal split in the stock (%)				
2W		76%	70.5%–73.4%	66%–71%
3W		2.4%	2.2%–2.3%	2%
4W		18%	21%–24%	23%–28%
Bus		0.6%	0.6%	0.5%
LCV		1.6%	1.6%–1.7%	1.6%–2%
MHCV		1.3%	1.3%–1.4%	1.3%–1.5%

** p implies that the value is projected*

Sources: United Nations, 2022; Ministry of Statistics Programme Implementation, 2022; Ministry of Road Transport and Highways, 2023c

Vehicle utilisation and emissions

Table C2: Assumptions for vehicle utilisation

Vehicle mode	AVKT (km/yr)	Average fleet mileage in 2022					
		Petrol (kmpl)	Diesel (kmpl)	Gas (km/kg)	EV (km/kWh)	HEV (kmpl)	FCEV (km/kg)
2W	6,000	50	-	-	26	-	-
3W (L5)	25,000	36	34	31	17	-	-
4W	10,000	18	20	23.5	7	25	-
Bus	45,000	-	4	2.5	0.9	5	-
LGV	35,000	10	8	22	5	13	-
MGV	45,000	-	4	8	0.7	6	18
HGV	45,000	-	3.5	7	0.5	4	18

Table C3: Emission factors of various fuels

Fuel		Scope	2022	2030	2035
Petrol	kg CO_2eq/l	WTT	0.64	0.64	0.64
		TTW	2.34	2.34	2.34
Ethanol	kg CO_2eq/l	WTT	0.97	0.97	0.97
			-	-	-
Diesel	kg CO_2eq/l	WTT	0.78	0.78	0.78
		TTW	2.57	2.51	2.47
Gas	kg CO_2eq/kg	WTT	0.92	0.94	0.95
		TTW	2.76	2.64	2.57
Electricity	kg CO_2eq/kWh	WTT	0.71	0.47	0.36
		TTW	-	-	-
Hydrogen	kg CO_2eq/kg	WTT	12	10	2
			-	-	-

Sources: Georg Bieker, 2021; Ministry of Power, Central Electricity Authority, 2023

Center for Study of Science, Technology & Policy

Bengaluru

#18, 10th Cross, Mayura Street, Papanna Layout,
Nagashettyhalli (RMV II Stage),
Bengaluru – 560094, Karnataka, India

Noida

1st Floor, Tower-A, Smartworks
Corporate Park, Sector-125,
Noida-201303, Uttar Pradesh,
India

www.cstep.in
+91-8066902500
cpe@cstep.in
@cstep_India