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What Drives Vehicle Ownership Costs in India?

A Segment-wise Analysis for India's Road Transport

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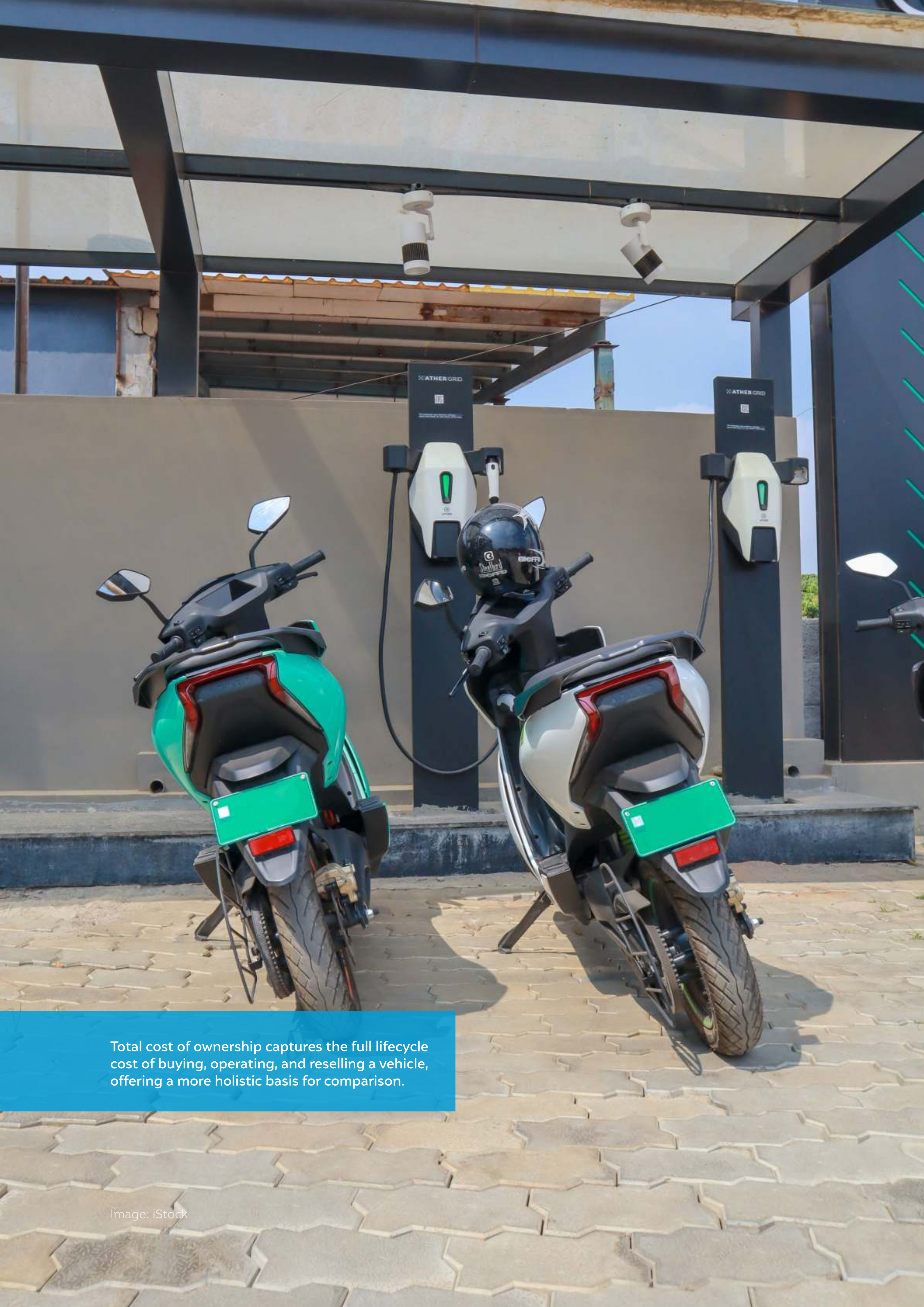

Total cost of ownership captures the full lifecycle cost of buying, operating, and reselling a vehicle, offering a more holistic basis for comparison.

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The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses **data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources**. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. CEEW is a strategic/ knowledge partner to 11 ministries for India's G20 presidency.

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Electric two-wheelers are already more cost-effective to own and operate than petrol models.

Image: Alamy

Contents

Electric three-wheelers are seeing a surge in registrations due to their lower total cost of ownership.

Image: iStock

Executive summary

The emergence of electric vehicles (EVs) has significantly shifted the focus toward the Total Cost of Ownership (TCO), driving a broader and more strategic evaluation of long-term vehicle expenses across the automotive industry. Consumers use TCO analysis, either directly or indirectly, to make informed, long-term vehicle purchase decisions. This analytical approach reveals the true costs of operating and maintaining vehicles throughout their life cycle, moving beyond the simple purchase price to uncover hidden expenses and opportunities. This analysis has proven particularly valuable for evaluating emerging vehicle technologies. For instance, when comparing electric vehicles (EVs) with traditional combustion engines, TCO analysis pinpoints exactly when and under what conditions these technologies reach cost parity. Several studies have used TCO as an instrument to investigate the uptake of different powertrain types, especially EVs (Hagman, et al. 2016; Liu, et al. 2021; Wu, Inderbitzin and Bening 2015; Palmer, et al. 2018; Bubeck, Tomaschek and Fahl 2016).

Consumers rely on total cost of ownership (TCO) analysis—directly or indirectly—when making vehicle purchase decisions

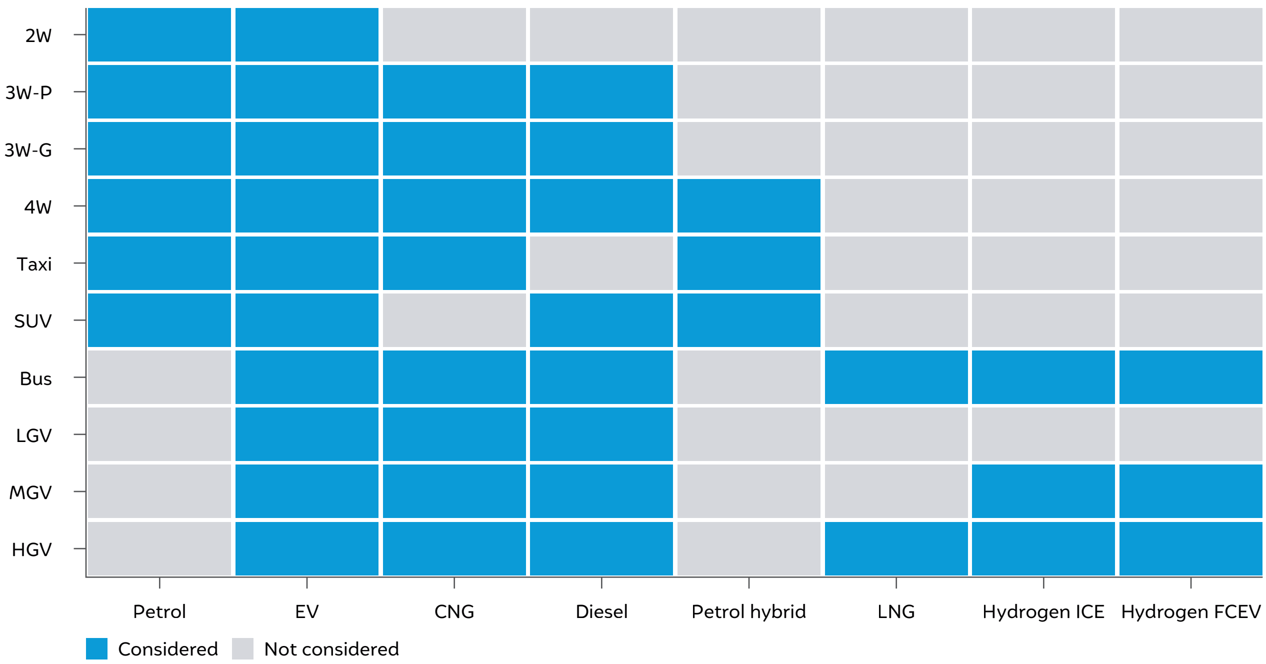
In the context OF the Indian automobile market, where consumers are highly cost-conscious, TCO plays a significant role in purchase decisions. It includes upfront downpayment costs, taxes, road tax, operating expenses including energy, maintenance, and insurance costs, and the resale value, providing a holistic assessment of costs incurred.

The following are the major parameters of TCO:

- **Capital costs**: The initial purchase price of the vehicle, including any subsidies or incentives.
- **Taxes and fees**: This includes Goods and Services Tax (GST), cess, and road tax, which can significantly impact the overall cost.
- **Fuel costs**: The cost of fuel over the vehicle's lifetime, which varies based on fuel type and market fluctuations.
- **Fuel economy and annual mileage**: The fuel economy refers to the efficiency of a vehicle in converting fuel into distance travelled, typically expressed as kilometres per litre (km/l) for conventional fuels or kilometres per kilowatt-hours (km/kWh) for electric vehicles. Annual mileage denotes the total distance a vehicle travels in a year, varying across different vehicle categories. Together, these metrics influence fuel costs and subsequently the TCO.
- **Loan and resale particulars**: The terms of any financing used to purchase the vehicle and its expected resale value at the end of its useful life.
- **Maintenance and insurance costs**: Regular maintenance expenses and insurance premiums, which are essential for keeping the vehicle operational and legally compliant.

Our study compares the TCO of different fuel types within ten distinct vehicle segments, shown in Figure ES1.

Figure ES1 Vehicle segments and fuel types considered in our analysis



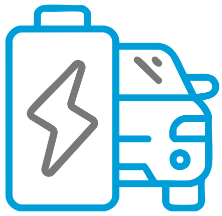
Source: Authors' compilation

Note: This analysis assumes diesel taxis are unavailable due to the widespread phase-out of diesel variants.

Key findings

- **Two-wheeler (2W)**: Electric two-wheelers are already cheaper on a TCO basis than their petrol counterparts, with a national average of INR 1.48 per km when compared to INR 2.46 per km for petrol. The relative lack of EV options, higher upfront costs, concerns around reliability, and accessibility of charging infrastructure are among the major reasons why the share of electric two-wheelers in total sales is still low.
- **Three-wheeler (3W)**: For three-wheeler passenger vehicles, CNG is, on average, a more cost-effective option compared to petrol and diesel. However, EVs remain the most economical choice on a TCO basis even in 2024, for both passenger and goods three-wheelers (3W-P and 3W-G). The cost hierarchy of fuels that are cheaper to own and operate is: EV (INR 1.28 per km), CNG (INR 2.35 per km), diesel (INR 2.69 per km), and petrol (INR 3.21 per km).
- **Four-wheeler (4W) and SUV**: For four-wheelers, EVs are cheaper on a TCO basis than other fuels in many states. However, in some states, due to higher charging tariffs and lack of road-tax waivers for EVs, the TCO for CNG and petrol are more competitive. Petrol-electric hybrid vehicles, often considered a good compromise between internal combustion engine (ICE) and EV, are significantly more expensive, making them uncompetitive in this segment against EVs. For the SUV segment, petrol and diesel will continue to remain much cheaper than their counterparts; petrol hybrids have a competitive TCO in some states where the fuel prices are higher.

- **Taxi**: For the taxi segment, running costs play a bigger role in the TCO than the capital costs, as taxis have a much higher annual mileage compared to private cars. This makes EVs substantially cheaper to own for taxi drivers. CNG is the next cheapest option, and taxis running on this fuel have been widely adopted in cities and districts that have a good CNG refuelling infrastructure. By 2030 and beyond, petrol hybrids may become another important option in some states where CNG availability is limited.
- **Bus**: The TCO of e-buses needs to reduce significantly to compete with diesel buses. CNG and LNG buses have a lower TCO on average than diesel buses but are limited by the respective distribution infrastructure. Green hydrogen buses will remain uncompetitive till the late 2040s, post which green hydrogen fuel cell electric vehicle (H_2-FCEV) buses have a lower TCO than green hydrogen internal combustion engine (H_2-ICE) buses due to their higher fuel efficiency.
- **Light Goods Vehicle (LGV)**: Among LGVs, EVs are much cheaper already in 2024. The usage patterns of LGVs, being primarily for short trips in more urbanised regions (also like 3W-G), make them more suitable for an EV transition.
- **Medium Goods Vehicle (MGV) and Heavy Goods Vehicle (HGV)**: For MGVs and HGVs, EVs are more expensive than diesel, CNG, and LNG in 2024. LNG is the cheapest fuel at present for HGVs, but refuelling infrastructure is nearly non-existent. While the TCO of electric M&HGVs will decline to become competitive beyond 2030, EV trucks will still be limited by a substantially lower range than diesel or gas-powered trucks (~250 km per charge vs ~600–800 km per refill). Thus, for the lower TCO to translate into market adoption, fast-charging capacity for heavy duty vehicles needs to be expanded significantly, and new battery technologies with higher energy density need to be commercialised. In addition, dedicated charging infrastructure needs to be deployed, with lower input costs of power to reduce the charging tariffs. Post 2040, H_2-FCEV trucks may become a suitable choice for long-distance routes, while electric trucks may get deployed on intra-district, short-haul segments.



Battery financing schemes that decouple the battery cost from the upfront cost could hasten the adoption of electric vehicles

Recommendations

- **Battery financing schemes**: Decoupling the battery cost of the vehicle from the capital expenditure (CAPEX) and instead charging a monthly rental/equated monthly installment (EMI) for the battery pack may prove beneficial to reduce the CAPEX burden on EV buyers. The Government of India, through public banks and non-banking financial companies (NBFCs), can provide a fixed scheme for battery rentals across all vehicle segments rather than relying solely on original equipment manufacturers' (OEM) schemes. Such a scheme can prioritise domestically manufactured battery packs for commercial/goods vehicles, where the assembled cost of the battery pack is repaid by the consumer as a loan at a fixed rate.
- **Establishment of LNG corridors**: LNG-powered buses and trucks currently have the lowest TCO in their respective segments. In states that have access to LNG terminals, refuelling stations can be established along key highways that have regular movement of buses and trucks. The government must revise and upkeep its target for deployment and operation of LNG stations and come up with standardised guidelines and regulations on setting up and operating LNG stations, and for selling LNG.

- **Data generation and transparency on running costs**: The government can empower leading institutions like the Indian Institutes of Technology, along with the Automotive Research Association of India (ARAI), to carry out public trials of diesel, CNG, EV, and H_2 buses and trucks on a comparative basis over a period of one year to generate data on maintenance costs, fuel efficiency, performance, etc. to better understand the status quo and avenues of improvements.

  State transport corporations and OEMs may provide operations and maintenance cost data in a more transparent manner by revealing the breakdown of the chosen gross-cost contract (GCC) tariffs. State transport authorities can also furnish running cost data on an annual basis for their diesel, CNG, and electric bus fleets separately.

- **R&D on emerging technologies for M&HGVs**: EVs are less competitive in the M&HGV segment, primarily because of limitations in battery range and extended recharging times. To enhance their competitiveness in this segment, more research efforts are required to improve energy density and reduce charging durations. Additionally, research efforts should also prioritise exploring diverse and advanced battery chemistries to support this transition.

  Green hydrogen FCEVs may be more viable for long-distance, heavy duty operations, offering refuelling times comparable to diesel while eliminating tailpipe emissions. However, green hydrogen FCEV trucks are currently six times more expensive than diesel trucks. Therefore, parallel research efforts are required to accelerate this transition and realise the potential of hydrogen in long-haul transportation.

  The government can create a consortium comprising OEMs, policymakers, researchers and scientists to prioritise and foster innovation and research and development. Such an initiative would not only drive technological advancements, but also ensure India remains globally competitive and aligned with international standards in emerging technologies.

1. Introduction

Image: iStock

The advent of electric vehicles (EVs) has brought a renewed focus on the total cost of ownership (TCO) concept, prompting a comprehensive evaluation of long-term vehicle expenses across the automotive industry. The TCO is the cost incurred per kilometre over the life of the vehicle for buying, driving, maintaining and selling a vehicle. It is a broad metric that sheds light on the total costs incurred while owning a vehicle over its lifecycle, looking beyond comparisons of only the capital cost at the time of purchase.

1.1 Need for total cost of ownership (TCO) based analysis

Calculating the TCO is essential for transport sector modelling and policymaking, as it allows for more precise long-term cost projections and impact evaluation of different policies (e.g., fuel taxes, subsidies, or emissions regulations) on the overall cost of various transport options. Comparisons in TCO also allow stakeholders to predict the adoption of new technologies and fuels based on the projected change in costs. By factoring in various costs over time, TCO helps in evaluating and modelling financial risks associated with different transport options. Several studies have used TCO as an instrument in investigating the uptake of different powertrain types, especially EVs (Hagman, et al. 2016; Liu, et al. 2021; Wu, Inderbitzin and Bening 2015; Palmer, et al. 2018; Bubeck, Tomaschek and Fahl 2016).

India has one of the largest and fastest-growing automobile industries in the world. Mohan et al (2025) examined the growth potential of various vehicle types based on expected changes in population and GDP. The study found that the total vehicle stock in the country is likely to grow by 2.2 times between 2023 and 2050. In this study, we use TCO to gauge the likelihood of energy transitions occurring in the transport sector, i.e., shifts from petrol/diesel to CNG, to electric, and also to green hydrogen. Based on prevailing and expected prices of vehicles, fuels, annual maintenance, etc., we evaluated the likely inflection points for such fuel transitions for each vehicle category considered by the Mohan et al (2025) study. We followed the guiding principle that in a highly cost-conscious and largely economically sensitive market, consumers will directly (in the case of fleet operators) or indirectly (in the case of individual consumers) make a purchase decision based on TCO.

Total cost of ownership (TCO) helps evaluate and model the financial risks of different transport options

1.2 Vehicle segments considered in the study

The vehicle categories (i.e. segments) considered in this study are broadly classified into ten:

Two-wheeler (2W): Both scooters and motorbikes were combined under this category.
Three-wheeler passenger (3W-P): Three- to five-passenger auto-rickshaws. e-carts (i.e., cheaper e-rickshaws that operate at lower speeds) were not considered, as they are a newer segment that is yet to be fully regulated.
Three-wheeler goods (3W-G): All cargo three-wheelers (other than e-carts).
Private four-wheeler hatchback/sedan (4W): All privately owned four-wheelers that do not meet the GST Council's definition of a sports utility vehicle (SUV) (Central Board of Indirect Taxes and Customs 2024).
Private four-wheeler utility vehicle (SUV): All privately owned four-wheelers that meet the GST Council's definition of an SUV (Central Board of Indirect Taxes and Customs 2024).
4W taxi (Taxi): All four-wheeler light passenger vehicles registered as taxis available for contract carriage.
Bus: Twelve-metre buses used for either stage or contract carriage; minibuses were excluded because publicly available data on vehicle registrations (i.e., the VAHAN portal) does not specifically identify minibuses and large vans.
Light goods vehicle (LGV): Cargo vehicles with a gross vehicle weight (GVW) of less than 7.5 tonnes, which refers to the total weight of the vehicle when fully loaded.
Medium goods vehicle (MGV): Cargo vehicles with a GVW between 7.5 and 12.0 tonnes.
Heavy goods vehicle (HGV): Cargo vehicles with a GVW greater than 12.0 tonnes.

We considered agricultural vehicles like tractors and tillers to be out of the scope of our analysis, as they perform specific tasks in each sector that do not necessarily amount to 'transportation'. Specialised vehicles like disabled-carriage vehicles, fire tenders, etc. were not included as they form a very small part of the overall vehicle stock.

1.3 Fuels and technologies considered

The powertrain types considered include the conventional ones (petrol, diesel, CNG) and also newer technologies (LNG, hybrid, electric, green hydrogen). We considered LNG as an option for buses and HGVs as they enable travel over longer distances using natural gas compared to CNG vehicles. We considered petrol-electric hybrids in the analysis even though there are only a few models on sale today, as there are plans to introduce more affordable hybrids by simplifying and indigenising the technology (Sorabjee 2024). For hydrogen-fuelled vehicles, we considered both green hydrogen fuel cell electric vehicles (H_2 FCEV) and green hydrogen internal combustion engine (H_2 ICE) vehicles. While the former is the more advanced and more efficient technology, the latter is substantially cheaper and can be produced by adapting existing engine designs and manufacturing facilities, thus bringing green hydrogen to the market more quickly. We analysed green hydrogen-fuelled vehicles in only the bus, medium- and heavy duty segments as an option to minimise refuelling times; for smaller vehicles, electrification is cheaper and much more energy efficient. The CNG option for two-wheelers is not considered in this study, as it is currently limited to a single OEM, and market adoption has yet to be ascertained. Table 1 shows the vehicle categories and their fuel types considered in this analysis.

Table 1 Vehicle categories and powertrains considered in this analysis

S. No.	Notation	Segment	Considered fuel types
1	2W	Two-wheeler	Petrol, electric
2	3W-P	Three-wheeler passenger	Petrol, diesel, CNG, electric (and legacy LPG)
3	3W-G	Three-wheeler goods	Petrol, diesel, CNG, electric (and legacy LPG)
4	4W	Private four-wheeler hatchback/sedan	Petrol, diesel, CNG, electric, petrol hybrid
5	SUV	Private four-wheeler utility vehicle	Petrol, diesel, electric, petrol hybrid
6	Taxi	Commercial 4W	Petrol, CNG, electric, petrol hybrid (including legacy diesel)*
7	Bus	Bus (12-metre)	Diesel, CNG, LNG, electric, hydrogen internal combustion engine (ICE), hydrogen fuel cell electric vehicle (FCEV)
8	LGV	Light goods vehicle; GVW < 7.5 tonnes	Diesel, CNG, electric
9	MGV	Medium goods vehicle; 7.5 < GVW < 12 tonnes	Diesel, CNG, electric, hydrogen ICE, hydrogen FCEV
10	HGV	Heavy goods vehicle; GVW > 12 tonnes	Diesel, CNG, LNG, electric, hydrogen ICE, hydrogen FCEV

Source: Authors' compilation

*Note: This analysis assumes diesel taxis are unavailable due to the widespread phase-out of diesel variants.

Liquefied natural gas (LNG) is currently the most cost-effective option for buses and heavy goods vehicles (HGVs), with hydrogen fuel cell vehicles likely viable by the early 2040s.

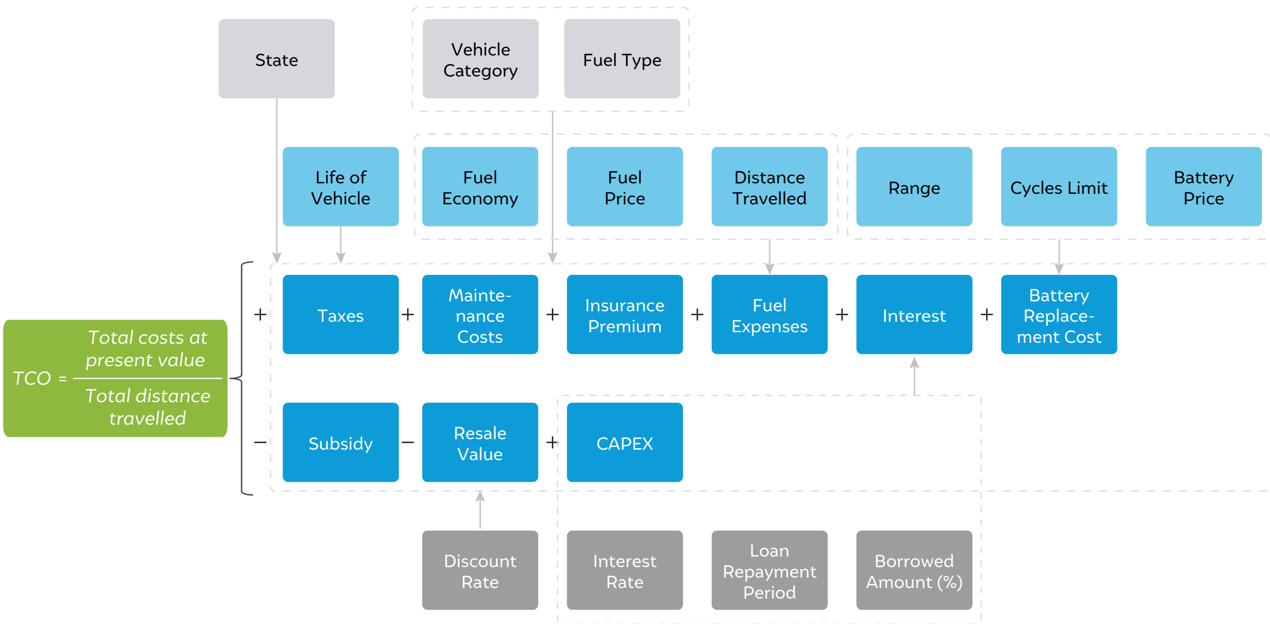
Image: CEEW

2. Parameters of TCO

The total lifetime costs of owning a vehicle can be broadly categorised into capital costs and operating costs. The capital costs include the upfront cost of buying a vehicle (or the capital expenditure, CAPEX), the taxes imposed by the central and state governments (goods and services tax, (GST) central excise and service tax, (cess) and road tax), and the interest payments (in case of a loan). The operating costs comprise fuel expenses, maintenance and insurance, recurring road tax (in the case of commercial vehicles), and battery replacement cost (in the case of EVs). The capital and operational costs are quantified for the vehicle types identified in Table 1 for future years from 2024 to 2050.

While the CAPEX and the fuel costs are the most significant components of the TCO, solely examining these two factors would not capture the intricacies between different powertrains. The upfront cost to buy a vehicle might be a burden in the initial years, but over a longer ownership period of 10 to 15 years, recurring costs such as insurance, maintenance, repair, and road tax gain more significance. So, it is imperative to establish sound methodologies to quantify these cost components to gain a holistic perspective of the TCO.

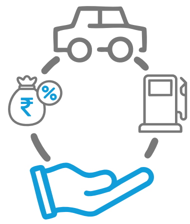
Figure 1 Analytical framework for estimating TCO in vehicle purchase decisions



Source: Authors' illustration

Note: Battery replacement cost is considered only for EVs.

The scope of this study is to estimate the TCO of different vehicle segments and their powertrains at a state level, and to compare powertrains within a vehicle segment. The TCO framework incorporates diverse parameters, some demonstrating uniformity across states; others displaying regional variability. Standardised parameters include CAPEX, interest payments, discount rate, resale value, GST and cess, and fuel economy. State-specific parameters include road tax, subsidies, and fuel prices. This comprehensive approach enables us to factor in state-level nuances in determining the cost of owning a vehicle.



The total cost of ownership varies across states due to differences in tax rates, fuel prices and subsidies

2.1 Capital costs

We obtained data on the model-wise sales for the year 2022–23 across vehicle segments from reports published by the Society of Indian Automobile Manufacturers (SIAM 2023). We used the top 90 per cent of best-selling models in each vehicle segment to calculate the weighted average prices reported by automotive websites (such as Carwale, BikeWale, TrucksDekho, etc.). These prices are given in Annexure 1. Then, for each state, we calculated the final price paid by the consumer (on-road price) by adding the GST and cess set by the central government, and the road taxes and subsidies set by the state governments (CEEW-CEF n.d., MoPNG 2024).

For simplicity, we assumed that the costs of vehicle types that use established technologies and fuels (such as petrol, diesel, CNG, and LNG) will be constant for the projected years. For newer technologies and fuels (such as EV, petrol hybrid, hydrogen ICE, and hydrogen FCEV), we assumed that the CAPEX would decrease over time due to reduction in battery and component costs, and technological improvements in fuel-cell vehicles. These assumptions largely hold true because the analysis is on a real currency basis. The only change in costs is due to the technical and commercial efficiency gain in green technologies. Any changes in material input, labour and other manufacturing costs will largely equally impact fossil or green fuel alternatives. We also assume that given the high maturity of ICE engines and the focus on green technology development, there might not be any significant improvement in ICE engine efficiency in the future.

- The price difference between petrol and petrol hybrid variant is around INR 3 lakh (Carwale n.d.). The average price of a Maruti Suzuki petrol car is around INR 9 lakh (CarDekho n.d.). Assuming the same price difference between petrol and petrol hybrids, we assumed that hybrids will be made available at INR 15 lakh by 2025–26, with the prices coming down to INR 12 lakh by 2030.
- We used projections by BloombergNEF (2023) that suggested lithium-ion battery prices would reach USD 80/kWh by 2030, from around USD 130/kWh currently. From 2030 onwards, we assumed the price remains at USD 80/kWh.
- We assumed H_2 ICE and H_2 FCEV trucks and buses to be about 2x and 5x that of a conventional diesel vehicle of comparable size and capacity (Office of the Principal Scientific Advisor to the Government of India 2023). With mass manufacturing, we expect the price premium of H_2 ICE to reduce to about 1.3x by 2035, based on approximate timelines provided by manufacturers. For H_2 FCEV, we assumed that the premium will linearly decrease to about 1.5–1.6x by 2050, as the technology is not mature globally and indigenisation will take time.

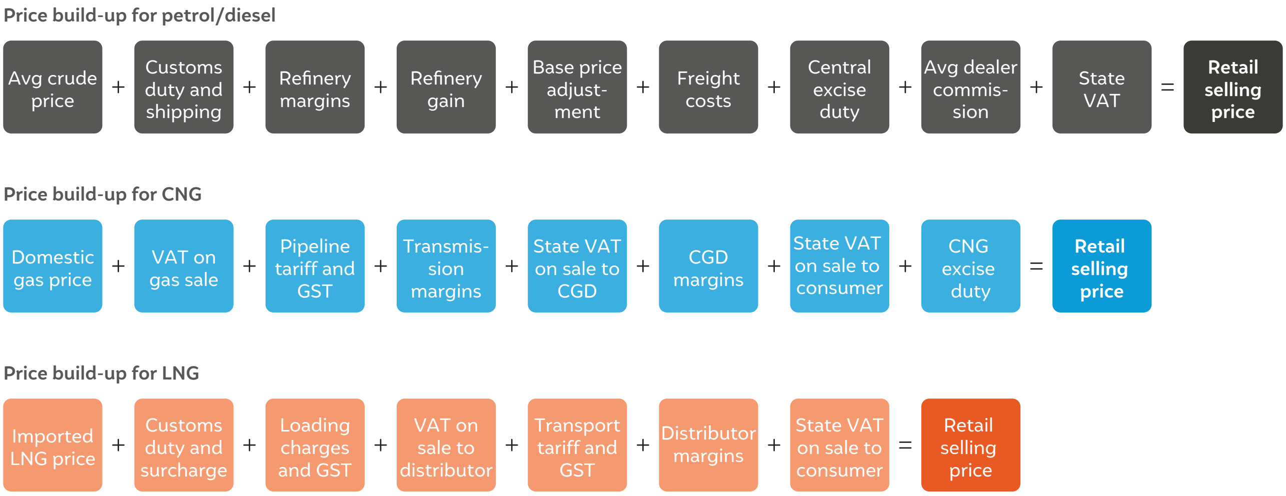
2.2 Fuel costs

Fuel costs often form the bulk of the TCO, especially for public vehicles like taxis, trucks and buses that cover long distances every day. In our analysis, we have six types of fuels: petrol, diesel, CNG, LNG, electricity, and green hydrogen. The following subsections explain the methods for projecting the fuel prices. The fuel prices used in the model are provided in Annexure 2: Fuel price assumptions and projections.

Petrol, diesel, CNG, and LNG

For petrol, diesel, CNG, and LNG, we used price build-up models that consider various costs and taxes along the supply chain to different states. This enables analysis of the impact of taxes and import prices.

Figure 2 Fuel price build-up formulae for petrol, diesel, CNG and LNG



Source: Authors' illustration based on MoPNG 2024. Indian Petroleum & Natural Gas Statistics. New Delhi: Ministry of Petroleum and Natural Gas; and Elango, Sabarish and Hemant Mallya 2021. Small-scale LNG for Expanding Natural Gas Access in India. New Delhi: Council on Energy, Environment and Water.

Figure 2 shows the price build-up formula for petrol, diesel, CNG and LNG. For petrol and diesel, the price build-up formula and data were obtained from MoPNG (2024). We assumed the past 10-year average crude price of 80 USD/bbl for all future years for the baseline estimation. We calibrated our price estimates by comparing the calculated retail selling prices with the actual retail selling prices in different states reported in 2023. We factored differences at a state level using an adjustment factor that accounts for differences in refinery outputs, margins, and freight costs.

For natural gas, retail price formulae or their components are not clearly defined in any publicly available reports. Thus, for CNG and LNG, we prepared internal price build-up formulae, building on existing CEEW research published in 2021 (Elango and Mallya 2021). Data on gas prices and taxes were obtained from MoPNG (2024) and Petroleum Planning and Analysis Cell (2024). We assumed dealer margins based on the financial reporting of different leading gas transmission and city gas distribution (CGD) companies (GAIL India Ltd 2023, Mahanagar Gas Limited 2023, Indraprastha Gas Limited 2023, Adani Total Gas Limited 2023).

Electricity

For electricity, we considered both residential electricity prices across different states and EV charging-specific tariffs for the states that have set them. Reports published by the Power Finance Corporation Limited (2022) provided the residential electricity prices as the average revenue per unit sold. The Bureau of Energy Efficiency (n.d.) provided the state-specific tariffs for EV charging stations for those states that have notified the same. We assumed that, by 2050, these input power tariffs will be 25 per cent lower due to dedicated access to cheaper renewable power, and lower energy storage costs.

For these public charging stations, we calculated the approximate tariff for three categories of chargers—3–9 kW AC (for 2W, 3W, and 4W); 10–30 kW DC and AC (for 4W and LGV), and >50 kW DC (for bus, MGV, and HGV)—based on the cost of setting up and operating charging stations (Cars24 2024, Shah 2019, DIYguru n.d., BSES Rajdhani Power Limited n.d.). On account of varied sources, we assumed capital costs of INR 50,000, INR 250,000, and INR 1.25 million for each of the above charger capacities respectively, with a 30 per cent overhead for miscellaneous equipment. We assumed annual operating costs to be about 35 per cent of the total capital costs (primarily going towards land leases). We also considered a revenue margin of 10 per cent.

Based on comparing EV charging tariffs with charging service providers Statiq (n.d.), we assumed that the 3–9 kW and 10–30 kW chargers have an effective capacity utilisation factor of 22 per cent (30 per cent for 18 hours/day and 350 days/year), which rises to 54 per cent (75 per cent for 18 hours/day and 350 days/year) by 2050. In 2024, electricity tariffs for the 3–9 kW category across all states range from INR 8.7/kWh to INR 18.2/kWh. Assuming a discount rate of 10 per cent, this range is projected to decrease to a range from INR 4.9/kWh to INR 11.8/kWh by 2050. For the 10–30 kW category, the tariff is currently between INR 8.2/kWh and INR 17.7/kWh and will decline to a range from INR 4.7/kWh to 11.6/kWh by 2050.

We assumed the 40–100 kW chargers to have an effective capacity utilisation factor of 29 per cent (30 per cent for 24 hours/day and 350 days/year), which rises to 72 per cent (75 per cent for 24 hours/day and 350 days/year) by 2050. In 2024, the electricity tariffs for the 40–100 kW category across all states range from INR 9.8/kWh to INR 19.1/kWh, declining to a range from INR 5.3/kWh to INR 12.1/kWh by 2050.

Green hydrogen

We obtained the current prices of green hydrogen for states having good solar and wind-solar hybrid generation potential (Mallya, et al. 2024). Based on the declining price trends expected, we assumed that the green hydrogen production costs will be USD 2–2.5/kg (depending on the state) in 2030, declining to about USD 1.5–1.9/kg by 2040 and USD 1.0–1.3/kg by 2050.

Similar to the electricity tariff calculations, we developed a model to calculate the cost of green hydrogen refuelling based on equipment and operating costs (Melaina and Penev 2013; Hecht and Pratt 2017; Eißler, et al. 2023). Publicly available data on refuelling costs in the present day typically indicate costs higher than USD 10/kg; this is due to the very small scale of refuelling networks and very low utilisation rates, such as in the state of California in the U.S. (Weeks and Soria 2024).

We took the green hydrogen compressor and storage costs given by Eißler, et al. (2023) for a 350-bar compressor. We referred to Hecht and Pratt (2017) for the capital costs of other equipment; we recalculated these costs for a larger station dispensing 1,000 kg H_2/day. We took five per cent of the total capital costs to be the annual operating costs. We assumed that the utilisation rate of the stations rises from 30 per cent in 2030 to 80 per cent by 2050. Based on these assumptions, and a discount factor of 10 per cent, we calculated the levelised cost of dispensation to be USD 2.2/kg in 2030, linearly declining to USD 0.8/kg by 2050. The overall costs of delivered green hydrogen thus range from USD 4.2/kg in 2030 to USD 1.8/kg in 2050.

2.3 Fuel economy and annual mileage

To calculate the annual fuel expenses for a given vehicle, we need the typical annual mileage (i.e., kilometres travelled) and the fuel economy (i.e., kilometres travelled per litre of fuel). We collected data on the real-world fuel economy of various vehicles on sale currently using information provided by reliable automotive reviewers (such as Autocar India), automotive information websites (like CarDekho, ZigWheels, etc.) or from studies (where up-to-date reviews were not available).

Table 2 Average fuel economy figures for different vehicle types

Vehicle segment	Petrol	Petrol hybrid	Diesel	CNG	LNG	Electric	H_2ICE	H_2FCEV
	(km/l)	(km/l)	(km/l)	(km/kg)	(km/kg)	(km/kWh)	(km/kg)	(km/kg)
2W	45.0					38.0		
3W-P	25.0		30.0	35.0		15.0		
3W-G	30.0		30.0	35.0		15.0		
4W	14.0	20.0	18.0	20.0		7.0		
SUV	9.0	18.0	12.0			5.0		
Taxi	14.0	20.0	18.0	20.0		7.0		
Bus			5.5	6.5	6.5	1.0	10.0	16.6
LGV			17.3	16.5		5.8		
MGV			7.7	9.1	9.1	1.5	12.0	20.0
HGV			5.0	5.9	5.9	0.8	9.1	15.1

Source: Authors' compilation from various sources

Table 2 shows the average fuel economy values considered for each vehicle type. We considered values for annual mileage based on the typical daily usage patterns of different vehicle segments. For instance, 2W are used primarily for commuting (distances vary between urban and rural regions), with increasing utilisation for food and courier delivery services. On the other hand, taxis, buses and trucks drive for much longer distances every day, as they are sources of income for their owners and operators.

Table 3 Annual mileage assumptions for different vehicle segments

Vehicle segment	Daily mileage (km)	Source	Annual mileage (km)
2W	30	Sati, Powell and Tomar (2021)	9,900
3W-P	100	Tigari and Santhosh (2020)	33,000
3W-G	100	Tigari and Santhosh (2020)	33,000
4W	35	Gupta (2018)	11,550
Taxi	200	Assumed	66,000
SUV	35	Gupta (2018)	11,550
Bus	225	Estimated based on fuel consumption	74,250
LGV	90	Malik and Tiwari (2017)	30,000
MGV	150	Malik and Tiwari (2017)	50,000
HGV	340	Estimated based on fuel consumption	85,000

Source: Authors' compilation

Note: Annual mileage estimates assume that the vehicles will operate for 330 days/year.

Table 3 shows the vehicle segment-wise daily and annual mileage assumptions. There is no country-wide survey data that provides such data across vehicle segments. Using regional survey data or data from specific case studies causes inaccuracies in the overall fuel demand. For example, we observed mismatches between the calculated versus total annual fuel demand given by MoPNG (2024). Using the segment/fuel-wise vehicle stock data from Mohan, et al. (2025), we tried to roughly estimate the total national fuel demand for past years for each vehicle segment using the formula:

$$Annual\ fuel\ demand = Vehicle\ stock \times \frac{Annual\ mileage}{Average\ fuel\ economy}$$

To correct any mismatches observed in the calculated versus actual total petrol and diesel consumption, we adjusted the mileage assumptions for different vehicle segments.

2.4 Loan and resale particulars

For all vehicle segments except bus, LGV, MGV, and HGV, we assumed that 20 per cent of the capital cost is paid by the buyer as a down payment, while the remaining 80 per cent is paid as monthly instalments. For the four aforementioned segments, we assumed that the entire cost of the vehicle is paid through instalments, and no amount is paid upfront.

We also considered the salvage value of the vehicle at the end of its useful life based on a fixed depreciation rate of 10 per cent from the capital cost. The average number of ownership years is derived from the medium survival rates, where the average ownership period corresponds to the point at which 50 per cent of registered vehicles in each segment are removed from the vehicle stock (Guttikunda 2024).

Table 4 Loan particulars for different vehicle segments

Vehicle segment	Ownership years	Loan repayment years	Interest rate (%)
2W	10	3	11.5
3W-P	13	4	23.1
3W-G	13	4	23.1
4W	11	7	8.1
Taxi	10	8	8.1
SUV	12	7	8.1
Bus	13	5	11.5
LGV	15	5	11.5
MGV	14	5	11.5
HGV	14	5	11.5

Source: Authors' compilation

Note: Interest rates and loan repayment years are averages compiled from various banks

2.5 Maintenance costs

Each vehicle type has different maintenance and servicing costs, depending on the complexity of the drivetrain, number of parts, wear and tear based on typical usage, etc. Internal combustion engine (ICE) vehicles have a larger number of moving parts compared to electric vehicles, thus having greater requirements for regular maintenance. However, EV batteries (which constitute a substantial portion of the vehicle cost) may need replacement after around 2,500 charge cycles (the batteries degrade with repeated cycles of charging and discharging, thus reducing range). We therefore considered annual maintenance costs in INR/km, along with battery replacement costs once or twice over the life of the vehicle (calculated based on the vehicle's range and number of charge-cycles it would undergo to cover the annual mileage assumptions in Table 3).

Table 5 Maintenance cost assumptions by vehicle type

Vehicle type	Fuel type	Insurance cost (%)	Maintenance cost (INR/km)	Note
2W	EV	1	0.22	Assumed same delta as 3W
2W	Petrol	1	0.31	
3W-P and G	CNG	1	0.64	
3W-P and G	Diesel	1	0.61	
3W-P and G	EV	1	0.42	
3W-P and G	Petrol	1	0.61	Assumed same as diesel
4W and taxi	CNG	0.9	0.50	Avg. of top-90% of best-selling models
4W and taxi	EV	0.85	0.28	Avg. of top-90% of best-selling models
4W and taxi	Petrol	0.6	0.30	Avg. of top-90% of best-selling models
4W and taxi	Petrol hybrid	0.8	0.58	Avg. of top-90% of best-selling models
4W	Diesel	0.9	0.5	Avg. of top-90% of best-selling models
SUV	Diesel	1.38	0.77	Assuming the difference as capex delta between 4W and SUV
SUV	EV	1.84	0.58	Assuming the difference as capex delta between 4W and SUV

Vehicle type	Fuel type	Insurance cost (%)	Maintenance cost (INR/km)	Note
SUV	Petrol	1.23	0.61	Assuming the difference as capex delta between 4W and SUV
SUV	Petrol hybrid	1.27	0.86	Assuming the difference as capex delta between 4W and SUV
Bus	CNG	1	13.36	Values for transit bus; taking ratio to diesel bus cost given by Vijaykumar et al. (2024)
Bus	Diesel	1	13.36	
Bus	EV	1	7	
Bus	H_2FCEV	1	10.2	Values for transit bus; taking ratio to diesel bus cost given by Vijaykumar et al. (2024)
Bus	H_2ICE	1	13.36	Assuming same as diesel
Bus	LNG	1	13.36	Values for transit bus; taking ratio to diesel bus cost given by Vijaykumar et al. (2024)
HGV	CNG	1	10.57	Average of single-unit and combination long-haul truck
HGV	Diesel	1	9.80	Average of single-unit and combination long-haul truck
HGV	EV	1	6	Assuming same price spread as bus (we account for battery replacement costs separately)
HGV	H_2FCEV	1	7.9	
HGV	H_2ICE	1	9.80	
HGV	LNG	1	10.57	
LGV	CNG	1	0.64	
LGV	Diesel	1	0.61	
LGV	EV	1	0.42	
MGV	CNG	1	10.32	
MGV	Diesel	1	9.80	
MGV	EV	1	6.75	Assuming same delta as LGV (we account for battery replacement costs separately)
MGV	H_2FCEV	1	6.75	Assuming same as EV
MGV	H_2ICE	1	9.80	Assuming same as diesel
MGV	LNG	1	10.32	

Source: Authors' compilation from Argonne National Laboratory 2023; Vijaykumar, et al. 2021; Altigreen n.d., and OTO 2024

Note: 1) Maintenance costs for 4W have been compiled based on the top 90% of best-selling models, using data from online car portals.

2) The insurance costs for 4W, taxi, and SUV are expressed on a per-kilometre basis

3. Results and discussion

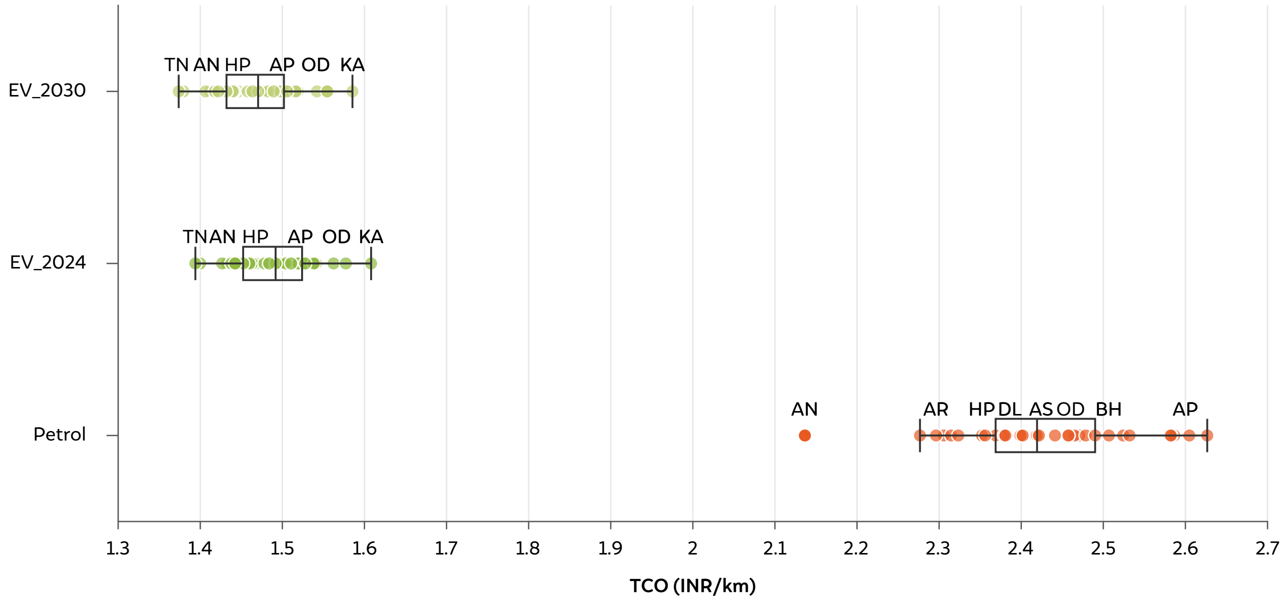
Image: Alamy

Based on the parameters mentioned in Section 2, we were able to calculate the TCO for each fuel type in a given vehicle category for different states for each year till 2050. This section shows the comparisons of TCO for various vehicle segments for all the states.

3.1 Two-wheeler

Figure 3 shows the TCO comparison for two-wheelers. Already, in 2024, electric 2W are cheaper on a TCO basis than their petrol counterparts. The estimates include the subsidies outlined under the PM e-drive scheme (actual values in 2024 and assumed values till 2026). The relative lack of EV model options, higher upfront costs, concerns around reliability and accessibility of charging infrastructure are among the major reasons why the share of electric two-wheelers in total sales is still low.

Figure 3 EVs are already cheaper to own and operate than petrol two-wheelers



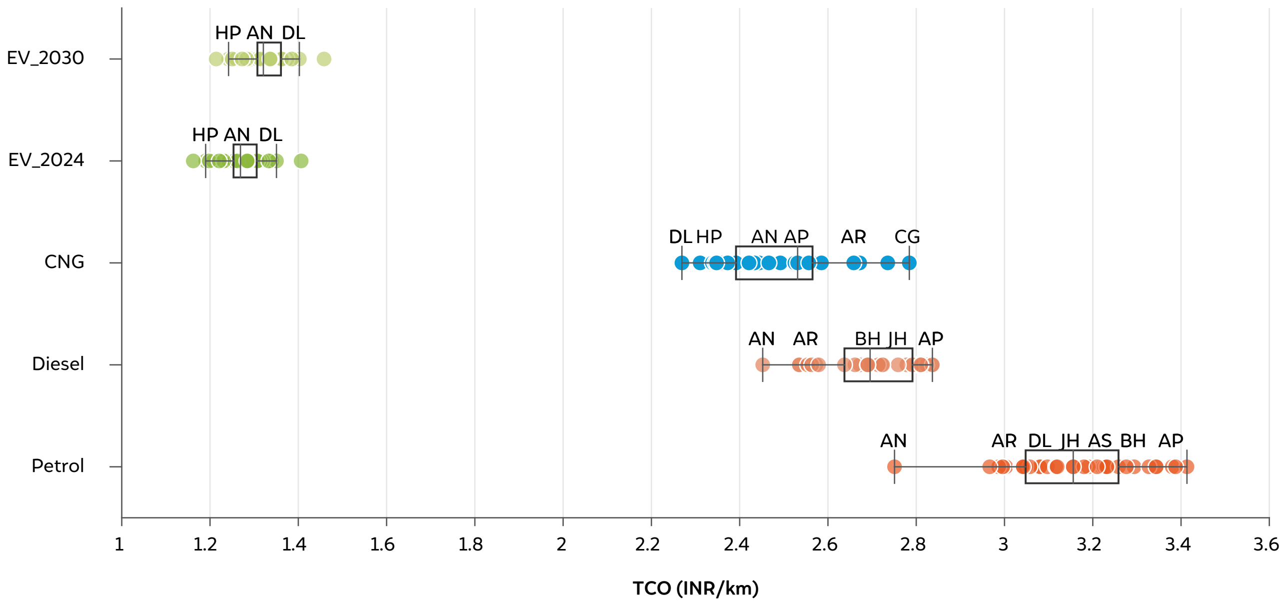
Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and union territories (UTs).

3.2 Three-wheelers

The comparisons in Figure 4 and Figure 5 show that, among the conventional fuels, CNG is a cheaper option for three-wheelers on average compared to petrol and diesel. However, EVs are again much cheaper on a TCO basis in 2024. The EV TCO could increase slightly towards 2030 and beyond; we assumed that the PM e-Drive subsidies will be gradually phased out. By 2050, we assumed that the charging tariffs would decline due to higher charger utilisation factors and lower input power costs (because of higher RE penetration in the grid and more dedicated RE and storage-based charging stations).

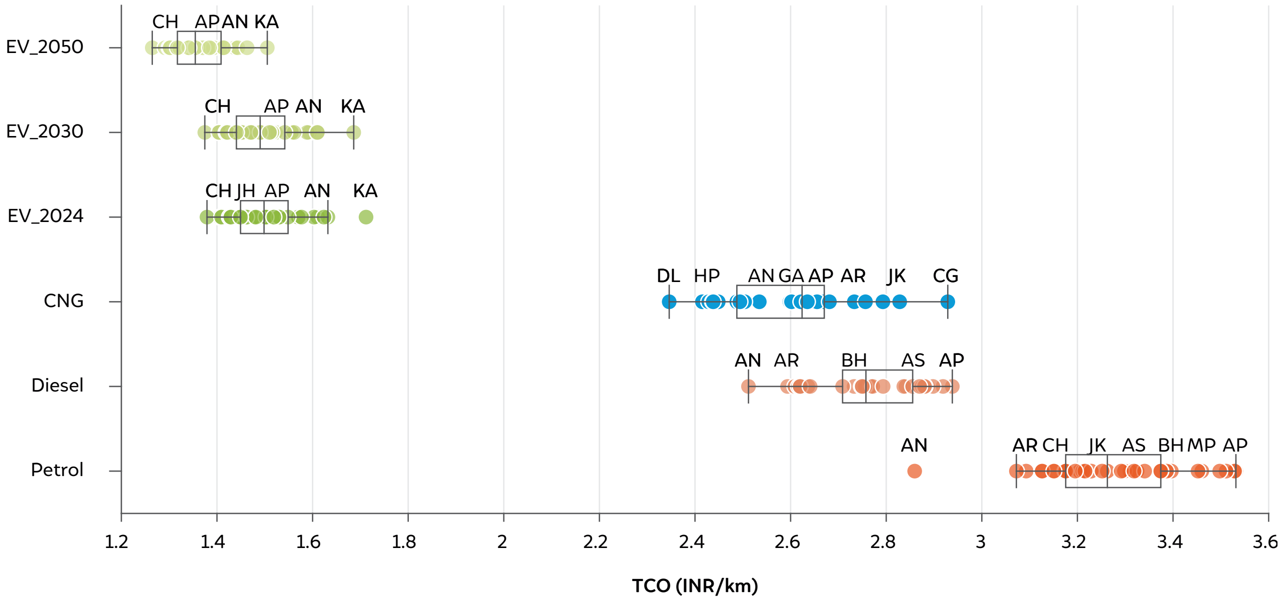
Figure 4 EVs are much cheaper to own for three-wheeler passenger vehicles



Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

Figure 5 Similar to 3W-P, EVs are cheaper to own and operate for 3W-G vehicles



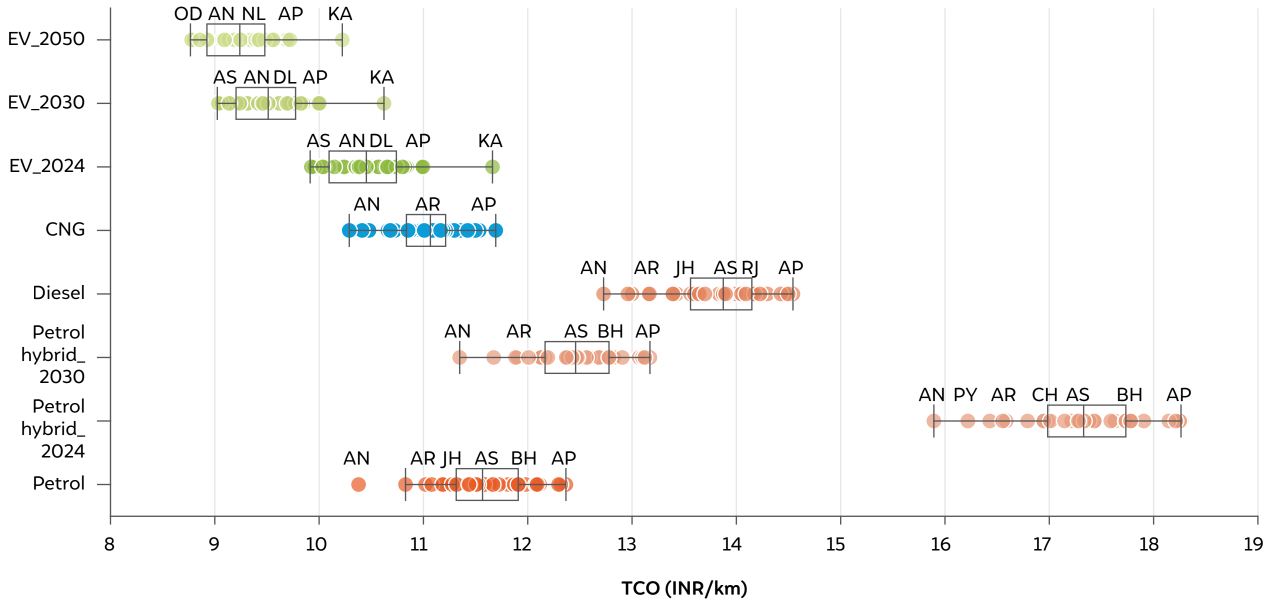
Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

3.3 Four-wheeler, taxi and SUV

For four-wheelers, too, EVs are cheaper on a TCO basis than other fuels in many states. The low GST and compensation cess rates for EVs (at 5 per cent instead of 37–43 per cent) has greatly reduced the CAPEX premium. Thus, EV purchase decisions are likely constrained by charging infrastructure, range anxiety, and reliability concerns, and not prices in these states. However, in some states such as Karnataka, due to higher charging tariffs and lack of road-tax waivers for EVs, the TCOs for CNG and petrol are more competitive. Petrol-electric hybrid vehicles, often considered a good compromise between ICE and EV, are significantly more expensive, mainly due to the high GST and compensation cess (at 43 per cent), making them uncompetitive in this segment against EVs. However, hybrids may still play an important role beyond 2030 as a compromise option between pure-ICE and pure-EV in many states where the hybrid TCO is competitive against CNG and petrol. Note that the CAPEX (i.e., down payment and financing costs) of diesel vehicles are high because diesel engines are now generally restricted to more premium vehicles; of the top-90 per cent best-sellers, the average price of petrol vehicles was INR 952,000, whereas that of diesel vehicles was INR 1,385,000.

Figure 6 Petrol hybrids may become more competitive with scale in production, reduction in GST and cess

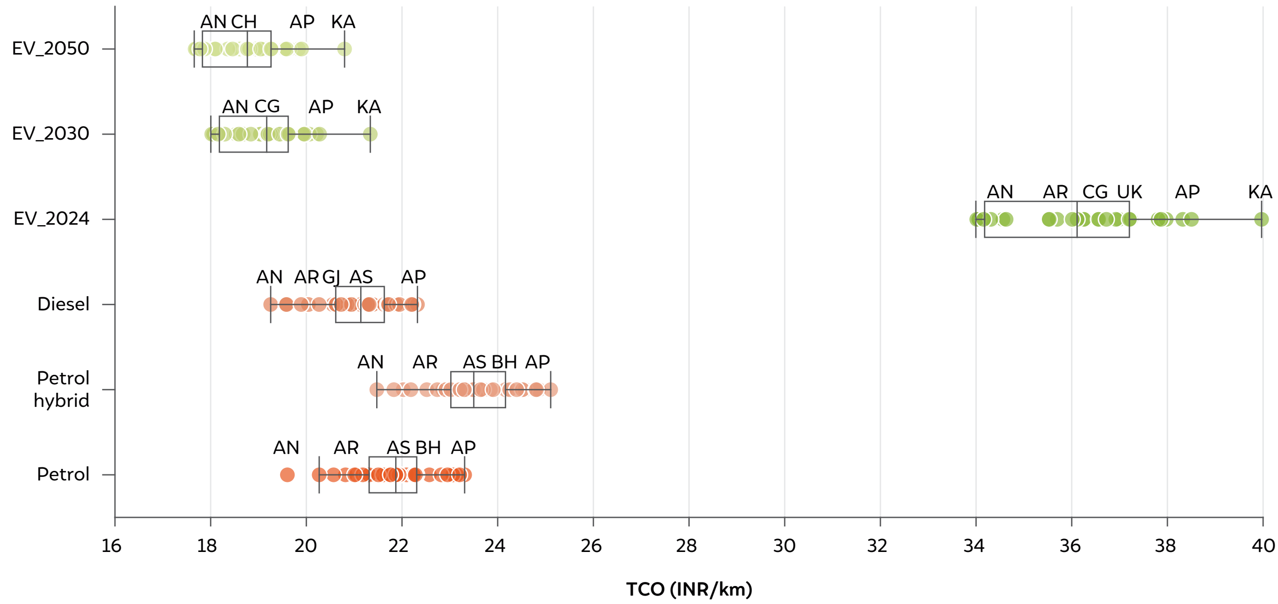


Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

For the SUV segment, petrol and diesel will continue to remain much cheaper than their counterparts for the foreseeable future; petrol hybrids have a competitive TCO in some states where the fuel prices are higher. However, the high EV TCO in 2024 is because of a lack of models on sale in the competitive price segments of INR 2–3 million (20–30 lakh). Several OEMs are planning to launch new EV models in this segment by 2030; the TCO then becomes cheaper on average than other options. However, considering that this segment consists of mainly aspirational vehicle buyers, we do not expect the lower EV TCO to be an important deciding factor in sales.

Figure 7 Diesel remains the cheapest to own and operate for the foreseeable future

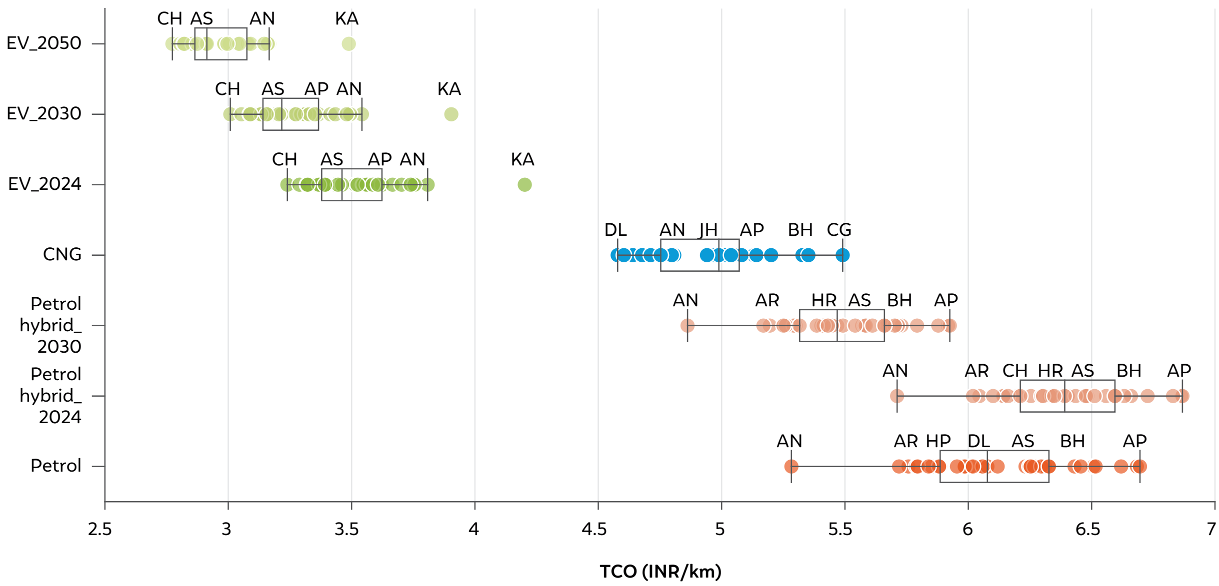


Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

For the taxi segment, running costs play a bigger role in the TCO than the capital costs, as taxis have a much higher annual mileage compared to private cars. This makes EVs substantially cheaper to own for taxi drivers; however, they are limited by insufficient public chargers and long recharging times. The next cheapest option is CNG; taxis running on this fuel are widely adopted in cities and districts that have a good CNG refuelling infrastructure. By 2030 and beyond, petrol hybrids may become another important option in some states where CNG availability is limited.

Figure 8 **EVs are highly competitive in the taxi segment due to their higher annual mileage**



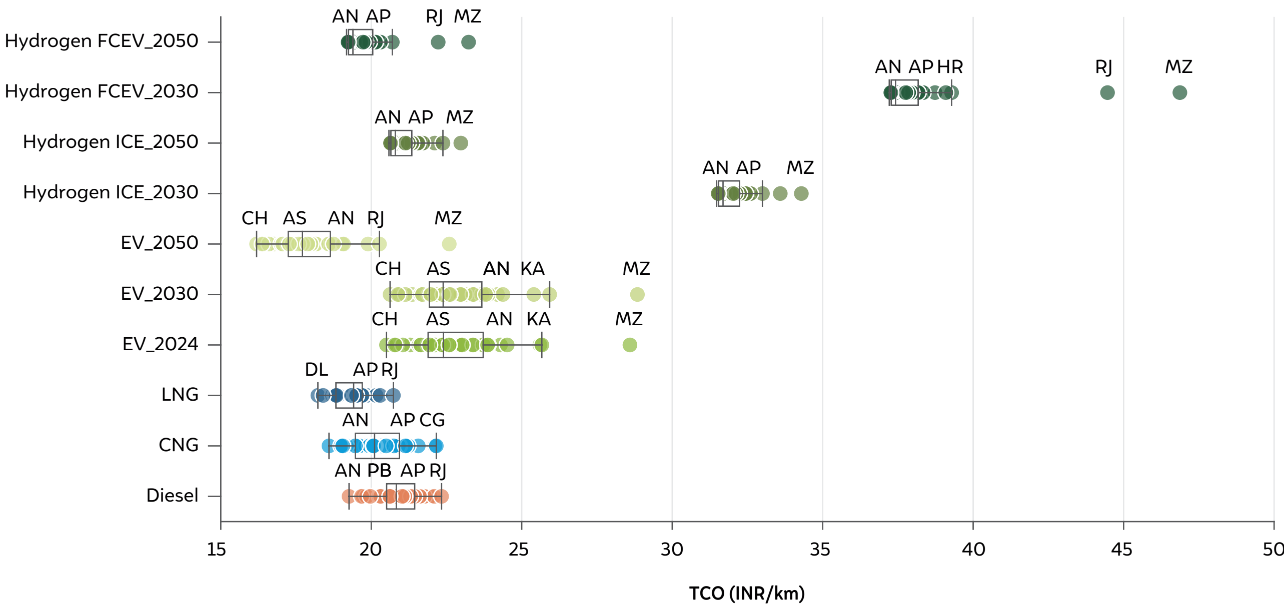
Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

3.4 Bus

Our analysis (Figure 9) indicates that the TCO of e-buses needs to reduce significantly to compete with diesel buses. The capital cost of e-buses is still much higher than diesel or CNG buses, even by 2030. Beyond 2030, we expect the e-bus TCO to decline, with larger-scale domestic manufacturing. Buses powered by CNG and LNG have a lower TCO on average than diesel buses but are limited by the respective distribution infrastructure. Hydrogen-powered buses remain uncompetitive till the late 2040s, post which H_2 FCEV buses have a lower TCO than H_2 ICE buses due to their higher fuel efficiency.

Figure 9 Gas-powered buses are cheaper than those running on traditional fuels



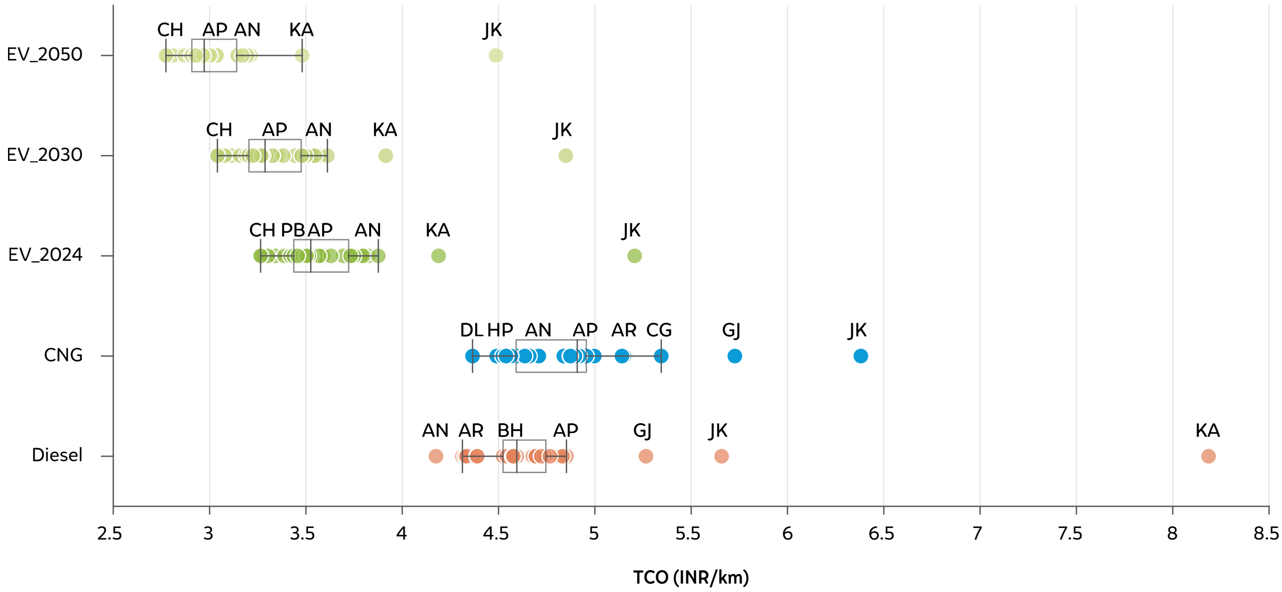
Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

3.5 Light goods vehicle (LGV)

For LGVs, the comparison is like that of 3W-G, with EVs being much cheaper already in 2024. The usage patterns of LGVs, being primarily for short trips in more urbanised regions (also like 3W-G), make them more suitable for an EV transition. Fleet operators of LGVs have a greater scope to adopt EVs, as they can also deploy charging stations in their own premises based on the fleet size, utilisation, and routes, making it more economical. For smaller operators, the higher upfront cost, lack of familiarity with EV operations/charging and relative lack of access to public fast chargers may prove detrimental.

Figure 10 EVs are again cheaper in the LGV segment



Source: Authors' analysis

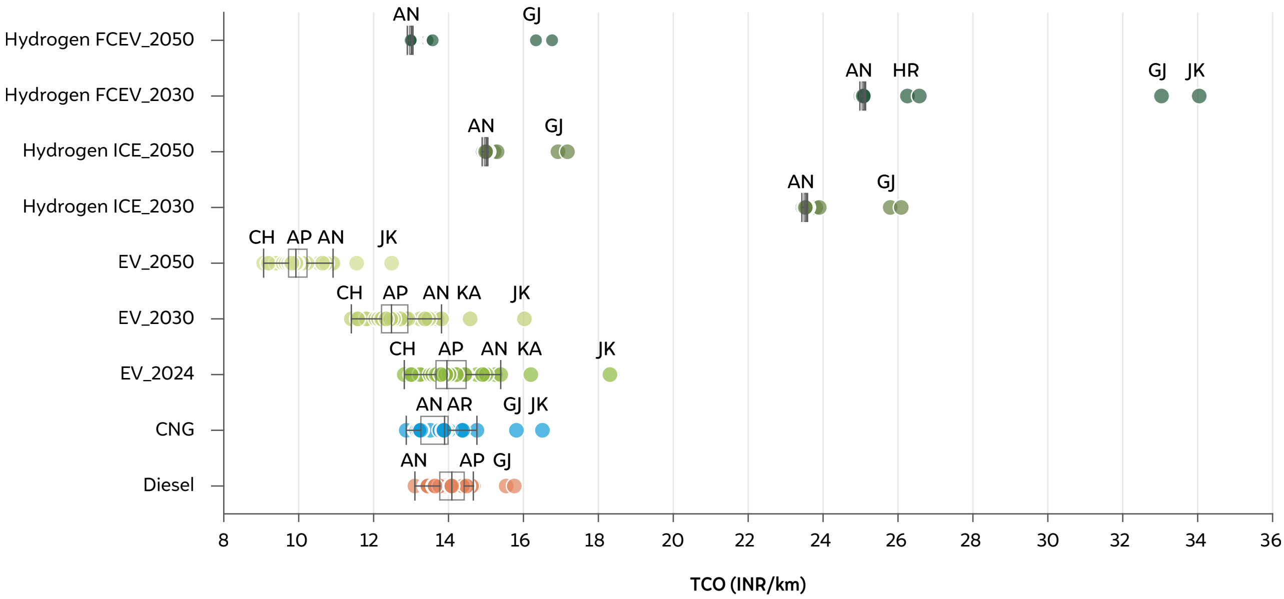
Note: The abbreviations denote official short forms of Indian states and UTs.

3.6 Medium and heavy goods vehicle

For M&HGVs, as seen in Figure 11 and Figure 12, EVs are more expensive than diesel, CNG, and LNG in 2024. At present, LNG is the cheapest fuel for HGVs, but refuelling infrastructure is nearly non-existent. While the TCO of electric M&HGVs will decline to become competitive beyond 2030, EV trucks will still be limited by a substantially lower range than diesel or natural gas-powered trucks (~250 km per charge vs ~600–800 km per refill). Thus, for the lower TCO to translate into market adoption, fast-charging capacity for heavy duty vehicles needs to be expanded significantly, and new battery technologies with higher energy density need to be commercialised.

In addition, dedicated charging infrastructure needs to be deployed with lower input costs of power (e.g., using dedicated RE and storage power plants instead of using grid power at commercial prices) to reduce the charging tariffs. We anticipate the cost of hydrogen-fuelled trucks to also decline steeply, considering the investments being made by Indian industry on green hydrogen. Post 2040, hydrogen fuel-cell electric trucks may become a suitable choice for long-distance routes, while electric trucks will get deployed on intra-district, short-haul segments.

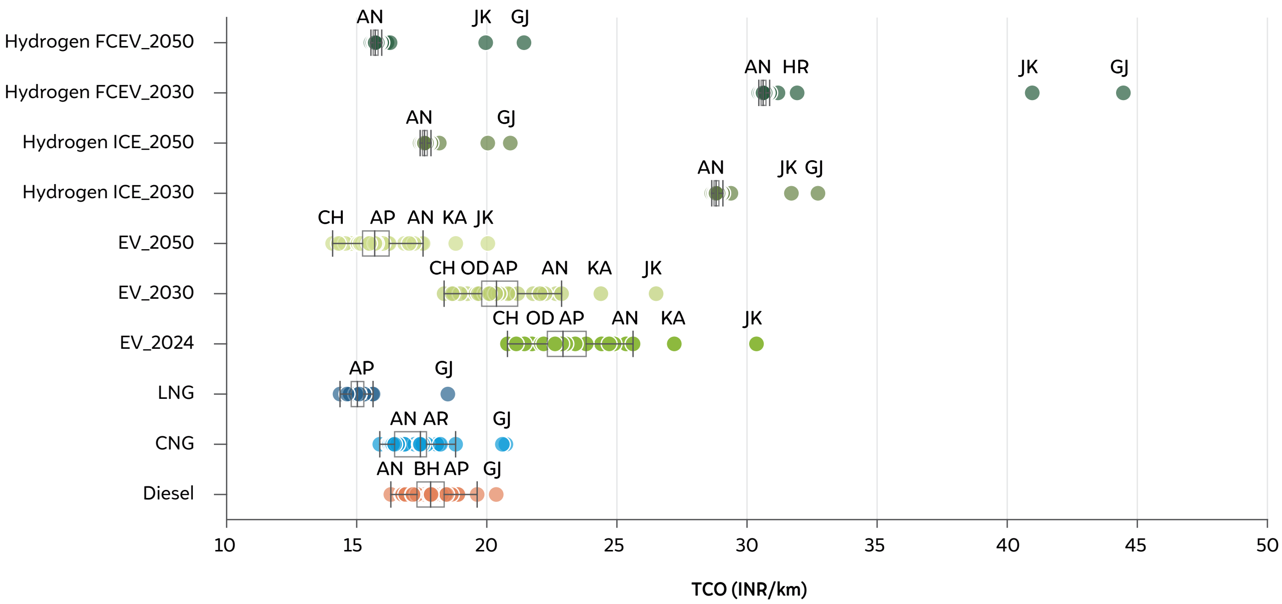
Figure 11 EVs will become competitive within the next five years in MGV segment



Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

Figure 12 Gas-powered HGVs—especially LNG—are the cheaper option in the immediate future



Source: Authors' analysis

Note: The abbreviations denote official short forms of Indian states and UTs.

4. Sensitivity analysis

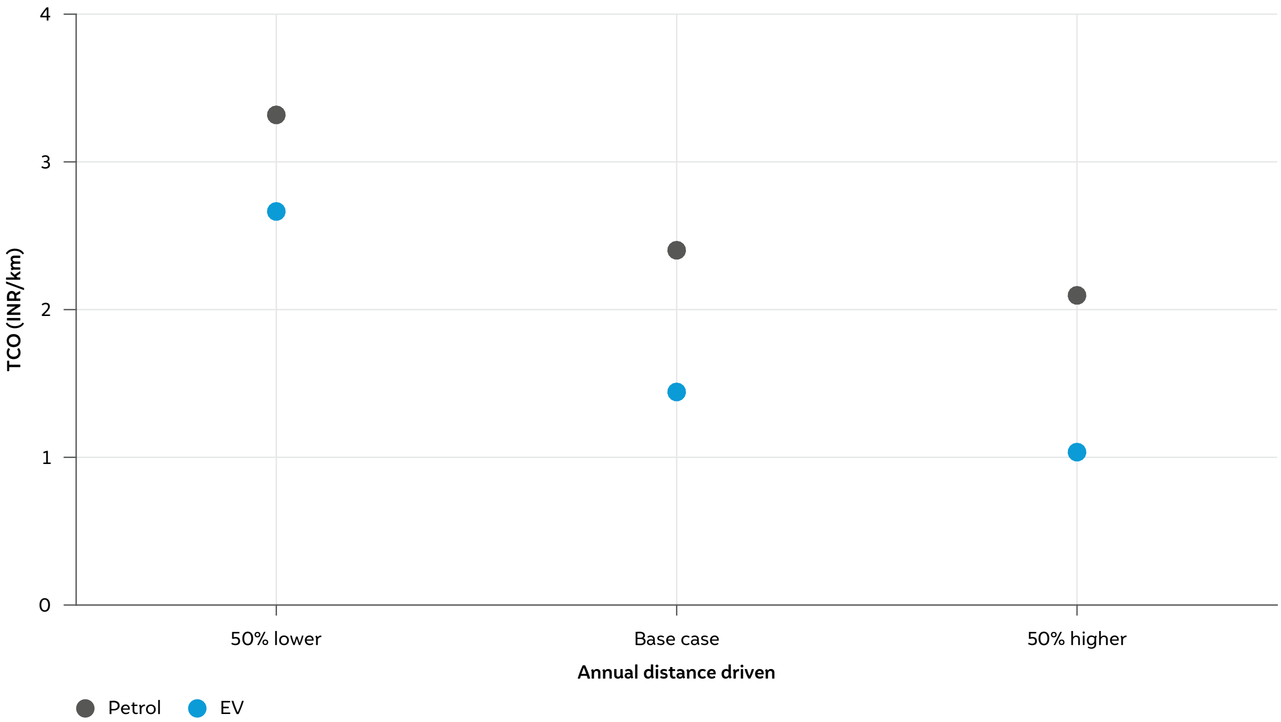
Image: iStock

Given the numerous parameters involved in estimating the TCO, and the uncertainties surrounding the lack of reliable data, we conducted a sensitivity analysis on some of the critical parameters of the TCO. These include annual distance travelled, maintenance cost, vehicle CAPEX, and fuel economy. Annual distance travelled and maintenance cost were adjusted by increasing them by 50 per cent and 100 per cent and reducing them by 50 per cent from the base case. Vehicle CAPEX and fuel economy were varied by ±10% and ±20% from the base case. This section presents the sensitivity results for selected vehicle categories and parameters. For each vehicle category, the state with the highest vehicle stock from Mohan, et al. (2025) and the parameter with the maximum deviation was chosen for illustration purposes.

4.1 Two-wheeler

Figure 13 illustrates the TCO difference between petrol and electric 2W in Uttar Pradesh under varying annual distance scenarios. The smallest TCO difference between petrol and EV TCO was observed in the 50 per cent lower scenario at INR 0.65 per km. As the distance driven increases, the cost gap widens, reaching INR 0.95 per km for the base case and INR 1.06 per km for the 50 per cent higher distance scenario. This indicates that as you drive longer, EV becomes the most affordable option for two-wheelers. For EV, a 50 per cent reduction in distance travelled leads to an 85 per cent increase in TCO, while a 50 per cent increase in distance results in 28 per cent decrease in TCO. For petrol, a 50 per cent reduction increases TCO by 38 per cent, and 50 per cent increase reduces TCO by 12 per cent. These trends indicate that EVs benefit more from higher usage as the other fixed costs (like CAPEX) are spread over more kilometres. In contrast, petrol 2W experience a comparatively smaller cost benefit with increased usage due to their higher running costs.

Figure 13 The TCO gulf between petrol and EV increases as the distance driven increases

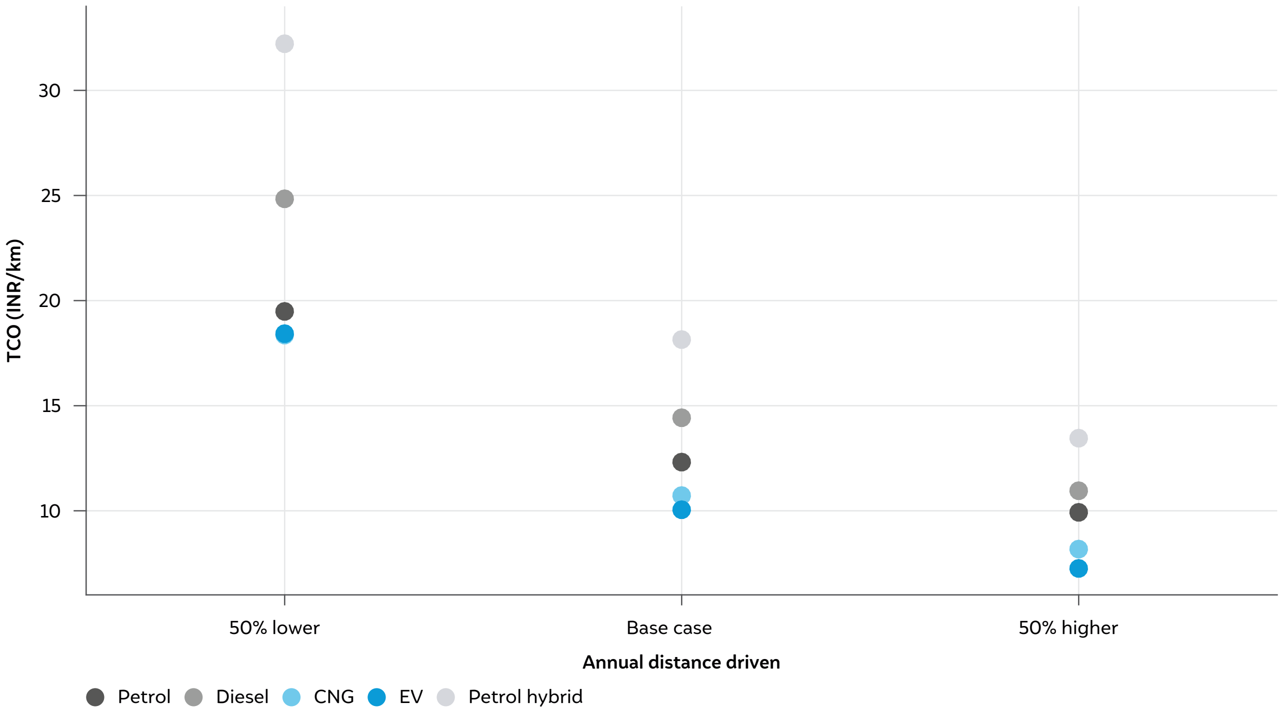


Source: Authors' analysis

4.2 Four-wheeler

Figure 14 describes the impact of annual distance travelled on the TCO for different fuels in Maharashtra. When the distance travelled is reduced by 50 per cent, CNG emerges as the most cost-effective option. Among all fuel types, the rise in TCO due to lower distances is highest for EVs and lowest for petrol. Conversely, when distance increases, the TCO reduction is most significant for EVs and least for petrol. If the distance driven is reduced by 50 per cent, the TCO increases by 83 per cent for EVs, 71 per cent for CNG, 72 per cent for diesel, 77 per cent for petrol hybrid, and 58 per cent for petrol. As the distance travelled increases, EVs become the cheapest option, with a TCO reduction of approximately 28 per cent. These trends indicate that CNG is the more cost-effective option for lower usage, while EVs provide cost benefits for high-mileage users. In contrast, petrol and diesel remain relatively stable and do not offer significant cost benefits with changes in distance.

Figure 14 CNG is the most affordable option for low usage



Source: Authors' analysis

4.3 Bus

Figure 15 illustrates the effect of distance travelled and maintenance costs on TCO for different fuels in Madhya Pradesh. Similar to four-wheelers, EVs experience the highest TCO increase when distance decreases, while diesel is the least affected. Conversely, the reduction in TCO due to higher distances is highest for EVs and lowest for diesel. Diesel, CNG, and LNG remain in a similar cost range if the distance is lowered, with CNG and LNG being the cheapest and EV the most expensive. As distance increases, the cost gap between CNG, LNG, and diesel widens. The most affordable option is LNG, followed by CNG and diesel. Electric vehicles have the highest TCO in both the base case and 50 per cent lower distance scenario, and it only marginally pips diesel if the distance travelled increases by 50 per cent.

In the case of maintenance costs, reduction in TCO due to lower maintenance costs is most significant for LNG and CNG, with decreases of 18 per cent and 17 per cent respectively, while EVs show the smallest reduction at 8 per cent. Similarly, an increase in maintenance leads to proportional rise in TCO, with LNG increasing by 18 per cent, CNG by 17 per cent, and EV by 8 per cent. For every 50 per cent change in maintenance costs, the impact on TCO is 17 per cent for CNG, 18 per cent for LNG, 16 per cent for Diesel, and 8 per cent for EV. Electric vehicles remain the most expensive option in all scenarios except one, where higher maintenance costs cause them to slightly surpass diesel, making them the third most affordable option after LNG and CNG.

Figure 15 LNG is the most affordable option irrespective of scenarios

Figure 15a) Sensitivity of Bus TCO to annual distance travelled

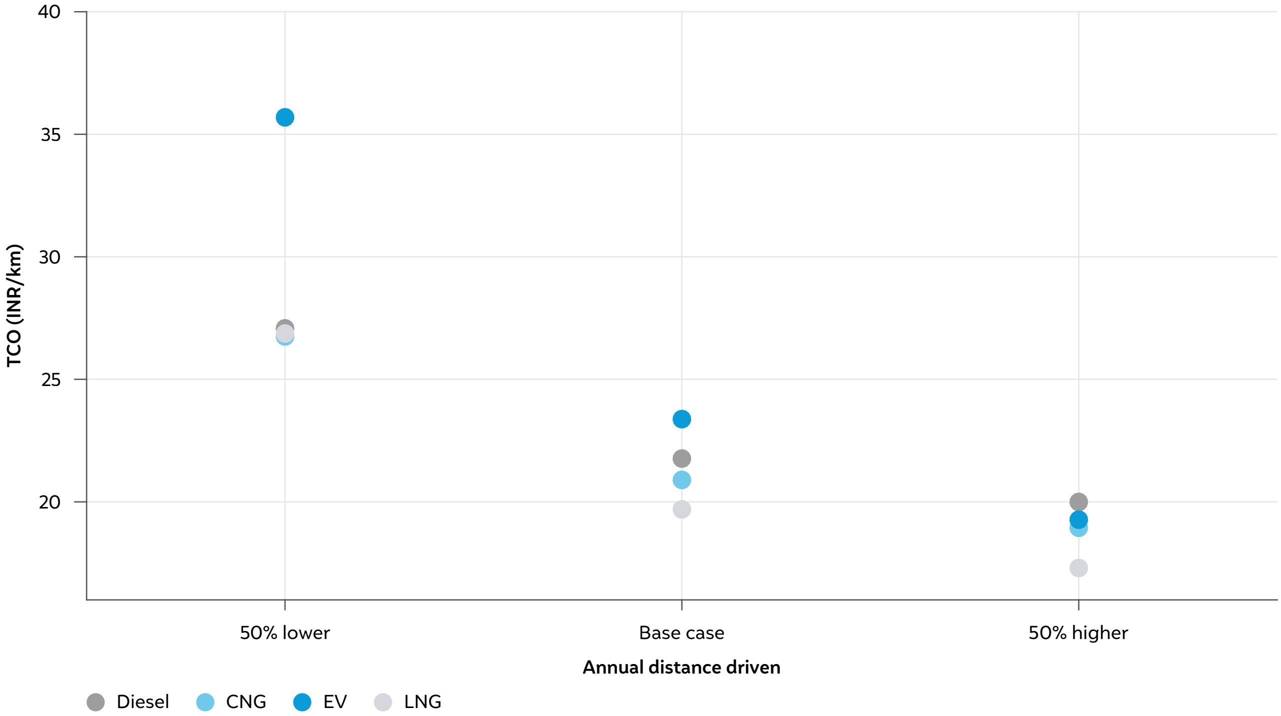
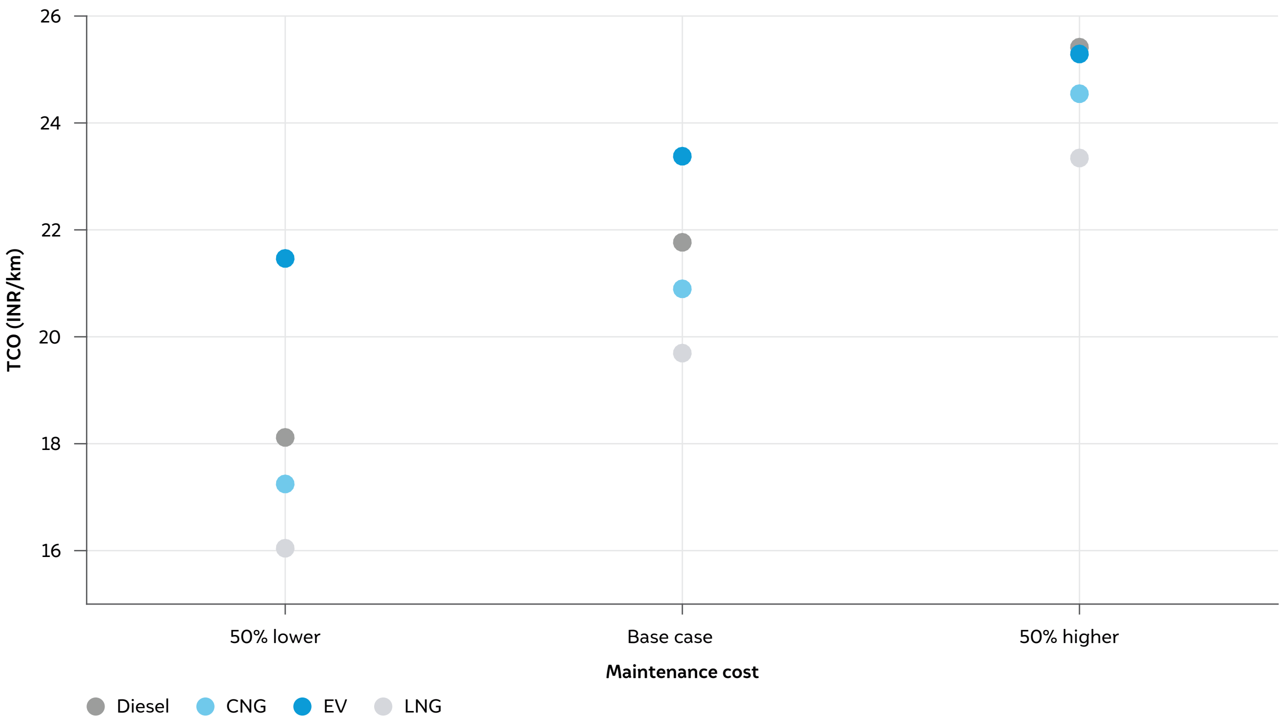


Figure 15b) Sensitivity of Bus TCO to maintenance costs



Source: Authors' analysis

4.4 Light goods vehicle (LGV)

Figure 16 illustrates the effect of distance and maintenance on the TCO for different fuels in Maharashtra. Electric vehicles experience highest TCO reduction with increased distance, while diesel sees the smallest impact. Similarly, EVs also have the highest TCO increase when distance is reduced, with diesel being the least affected. Regardless of distance travelled, EVs remain the most affordable option across all scenarios. The maintenance cost has a minimal impact on TCO for this vehicle category, as fluctuations affect all fuels in similar proportions.

Figure 16 Maintenance cost is not a sensitive parameter for LGV

Figure 16a) Sensitivity of LGV TCO to annual distance travelled

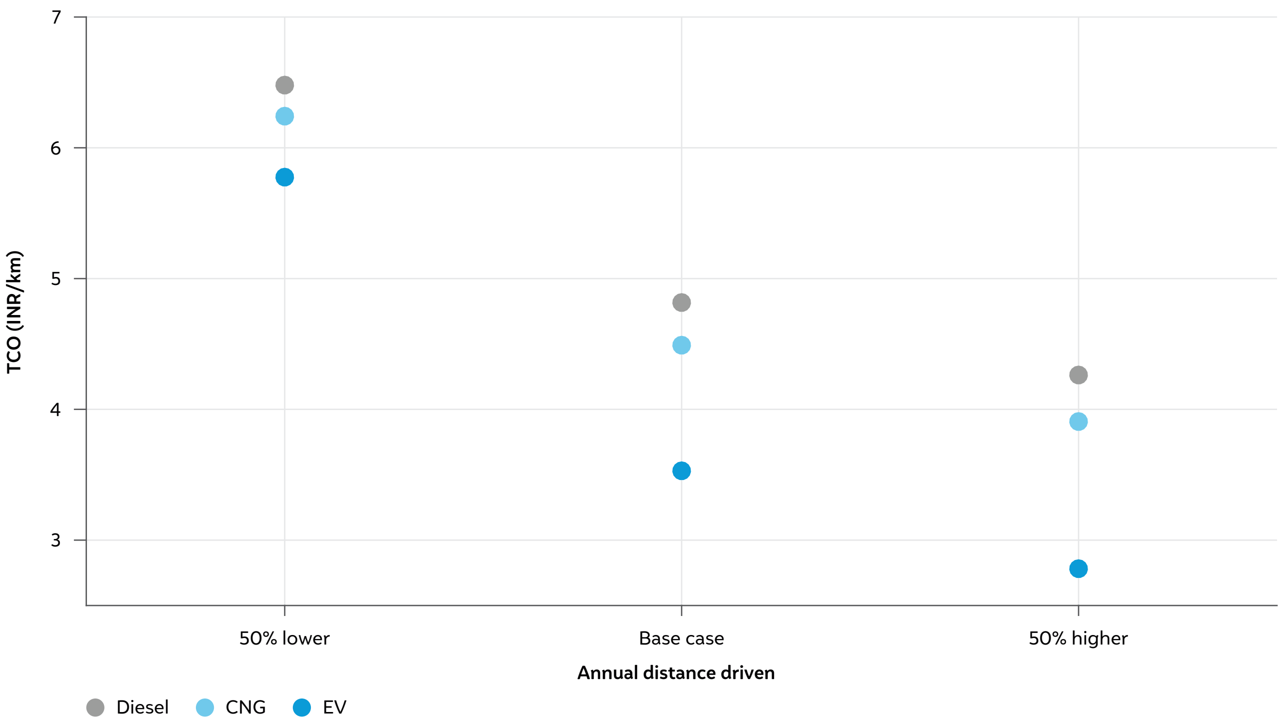
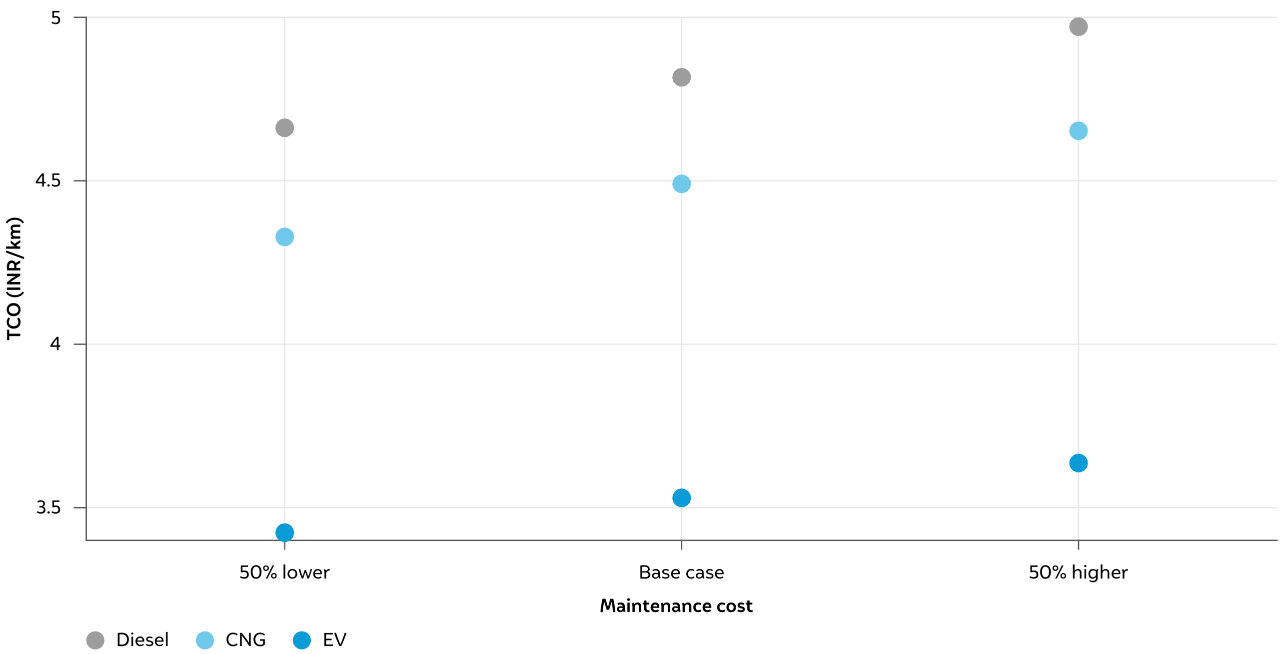


Figure 16b) Sensitivity of LGV TCO to maintenance costs



Source: Authors' analysis

4.5 Heavy goods vehicle (HGV)

Figure 17 describes the impact of annual distance travelled and maintenance costs on TCO for different fuels in Maharashtra. The HGV category follows a similar pattern to LGVs, where EVs are the most impacted by distance travelled, while diesel is the least affected. As distance increases, the cost gap narrows between EV and other fuels, but even with a 50 per cent higher distance than the base case, EVs still remain the most expensive option, whereas LNG remains the most affordable option across all scenarios; LNG and CNG are the most sensitive to maintenance cost variations, while EVs are the least affected. For every 50 per cent variation in maintenance costs, the impact on TCO is 19 per cent for LNG, 17 per cent for CNG, 14 per cent for diesel, and 7 per cent for EV. As maintenance costs increase, the cost gap narrows between EV and other fuels, yet LNG remain the most economically viable option in all cases.

Figure 17 EVs are most sensitive to variations in distance travelled, while LNG is most sensitive to changes in maintenance costs

Figure 17a) Sensitivity of HGV TCO to annual distance travelled

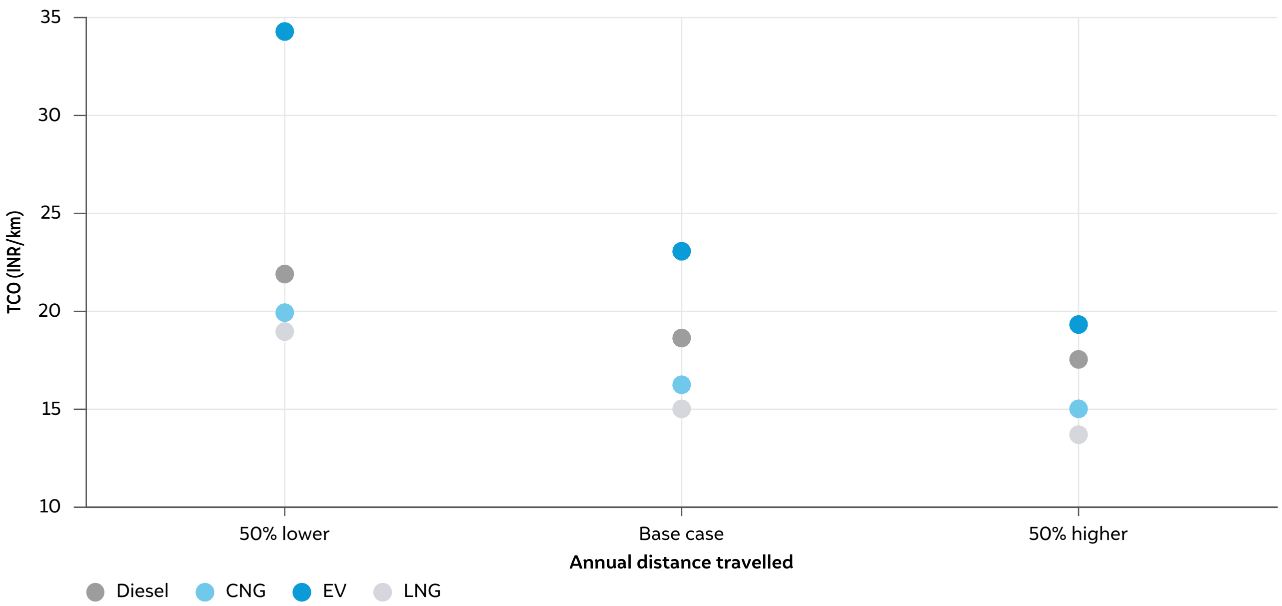
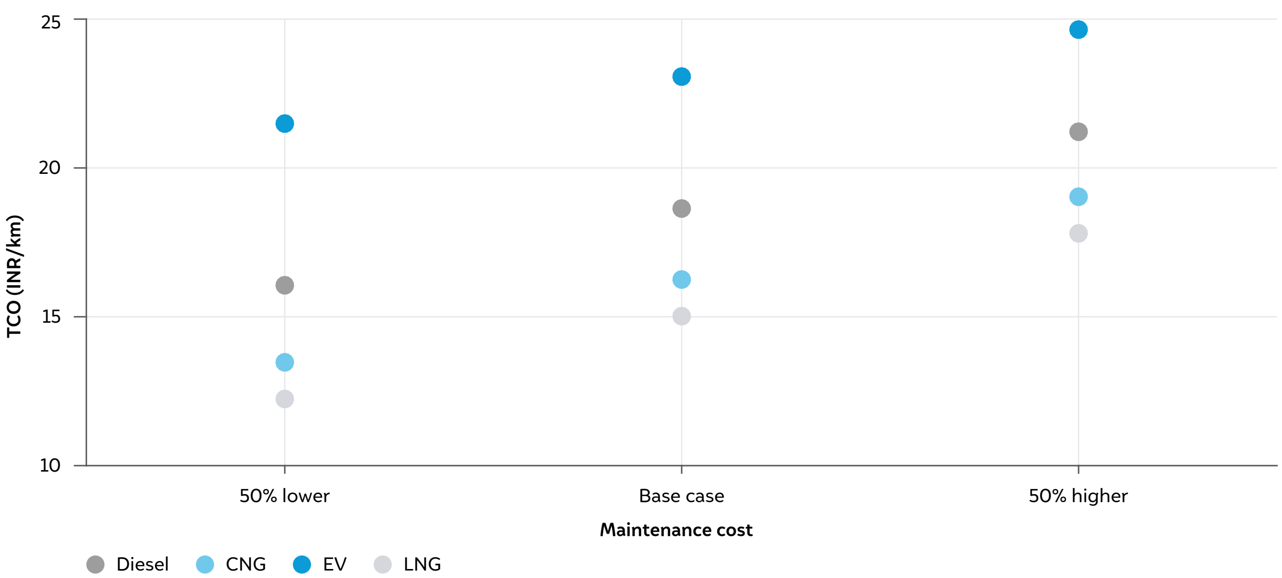


Figure 17b) Sensitivity of HGV TCO to maintenance costs



Source: Authors' analysis

5. Conclusions and policy recommendations

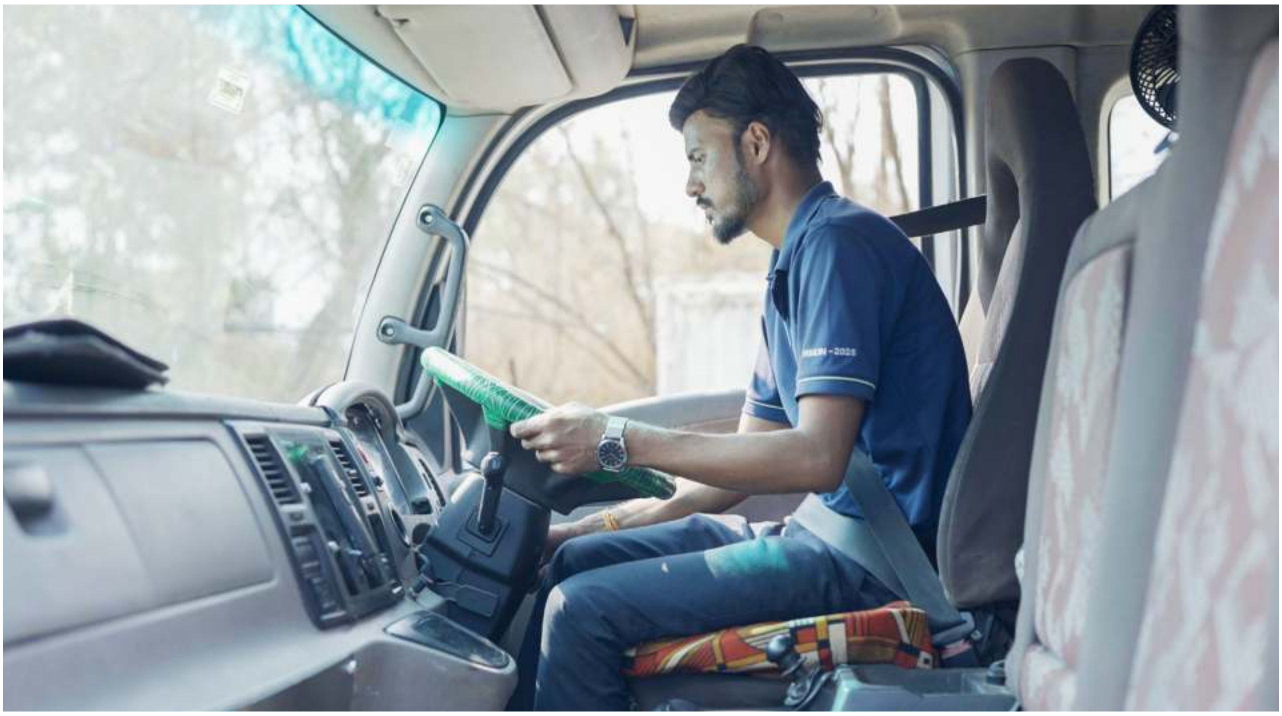


Image: PlucTV

Our analysis has presented a comparison of total cost of ownership across different vehicle categories and fuel types for different states. The following sections discuss the overall findings and limitations.

5.1 Limitations and data uncertainties

Capital costs

- The sales data to estimate the capital costs for top-selling models for commercial vehicle segments was not available from SIAM. We instead relied on representative models and costs from various OEMs operating in the commercial space.
- The capital costs of EV powertrains are based on an overarching assumption that battery prices and associated balance-of-system costs will decrease over time. Likewise, the cost projections for hydrogen-powered vehicles assume reductions due to technological advancements in fuel cells.
- The cost projections for traditional powertrains (petrol, diesel, and CNG) remain constant over time. However, this doesn't hold true if the government mandates stricter emission norms.

Fuel costs

- We have based future crude and gas prices on the past 10-year average. Historically, these prices demonstrate cyclical patterns, influenced by global demand and geopolitical factors, making it challenging to forecast a definitive trend for the future.
- We assume by 2050, EV charging costs will reduce with increasing charger utilisation rates and lower input tariffs by 25 per cent. This scenario is realised only if the location of the charger is strategic, and high RE deployments result in lower input tariffs.
- Region/state-wise data on fuel sales was not available; we therefore could not accurately capture regional trends in fuel type or costs.

Fuel economy and annual mileage

- Fuel economy assumptions for EV and H_2 trucks are based on data from AFLEET and other sources (Argonne National Laboratory 2023); these could be different in the Indian context as the design and operational parameters of such vehicles are varied.
- Annual mileage assumptions have been taken at a vehicle segment-level. However, within segments, there will be significant variations in usage that have not been captured due to lack of data. Some studies stratify the utilisation of 2W and 4W for urban commutes, but this data does not account for other non-commute-related trips.
- For buses, there is insufficient data to stratify utilisation for city buses, intercity buses, staff/school buses, etc.

Vehicle life

- The TCO calculation annualises all costs and divides the sum of the annualised costs by the annual distance. Thus, the number of years for which a vehicle stays in the fleet plays a significant role in the TCO. In our analysis, we have used the medium survival rates given by Guttikunda (2024) to estimate the vehicle life.

Maintenance costs

- Data on annual per-km maintenance costs is sparsely available. We used a combination of various sources to arrive at the maintenance costs by fuel type for different vehicle segments. These values may change based on technological advancements, indigenisation of components, etc.

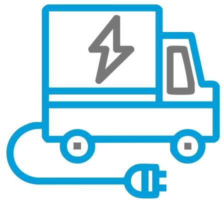
Since the goal of this study is to compare the costs of various powertrains within a vehicle segment, we have excluded certain cost parameters that are consistent across fuel types within a segment. For example, staff costs are a key component in calculating the TCO for a bus, but this cost remains unchanged regardless of powertrain, so it has been excluded. Similarly, toll charges are part of the TCO, but they have been consistent across fuel types within a segment.

5.2 Overall conclusions

Our comparisons show that for most vehicle segments, EVs are cheaper to own than their ICE counterparts by a fair margin. Among ICE powertrains, CNG and LNG are typically cheaper than average than petrol and diesel vehicles. Thus, for economically conscious buyers, which form a large portion of India's automobile market, alternate fuel vehicles are already more promising.

However, in all cases, the lack of suitable public infrastructure likely constrains the demand growth for these vehicles, apart from other considerations like driving range, reliability, recharging time, etc. For example, in the case of CNG, those states and districts that have a substantial number of CNG stations are seeing high levels of such vehicle registrations, especially in the commercial segment (VAHAN 2024). With expanding CNG infrastructure, demand for the fuel will rise due to the lower TCO.

In the case of EVs, segments such as 2W and 3W are already seeing surging registration numbers driven by the lower TCO. The difference in TCO of EVs versus other fuels is highest for these two segments. For 4W, the EV TCO is similar to CNG and petrol TCO; consumers may prefer the conventional fuels as the upfront cost is low and refuelling infrastructure is more widespread. For taxis, the EV TCO is much lower than both petrol and CNG. In Delhi, for example, electric taxis are able to compete with CNG equivalents as there are widespread charging hubs. However, in other regions, EV taxis are yet to become popular. For larger vehicles like trucks and buses, efforts are needed to make the TCO more competitive with traditional fuels. Higher levels of indigenisation of EV powertrains and local production of cost-competitive batteries are required to reduce the capital costs.



EVs are cheaper to own than ICE vehicles in most segments while LNG is cheapest for buses and HGVs

Petrol hybrids are a good middle-ground option, as they offer a compromise between range and efficiency, but they suffer from high GST rates, making them less competitive. A revision in GST rates for hybrids for specific segments like taxis may be evaluated.

The TCO of LNG is the lowest for HGVs. Dedicated road-freight corridors can be established in those road routes/districts that are in proximity to LNG terminals; LNG trucks can have a range of over 1,000 km on a single tank, making regular routes viable.

On hydrogen, given the fact that the TCO becomes cheaper only beyond 2040, efforts can perhaps be focussed on FCEV powertrain indigenisation rather than H_2 ICE as the former is much more energy efficient. Hydrogen-fuelled vehicles may make sense only for long-distance, heavy duty operations, where battery EVs may be limited by range, weight, and charging time.

5.3 Recommendations

- **Battery financing schemes**: While EVs offer far lower running costs, the upfront cost of EVs continues to be 30–40 per cent higher than petrol or CNG vehicles, despite substantial GST, cess, and road-tax benefits. Because most vehicle buyers are highly price-conscious, taking on the additional CAPEX burden may not be a viable option, especially for commercial buyers who typically purchase vehicles through a loan. Therefore, decoupling the battery cost of the vehicle from the CAPEX, and instead, charging a monthly rental/EMI for the battery pack, may prove beneficial. MG Motor India has recently announced a similar scheme, where the cost of the battery is removed from the initial price and buyers pay a fixed cost for the battery pack based on their mileage (MG Motor India 2024).

  The Government of India, through banks and non-banking financial companies (NBFCs), can provide a fixed scheme for battery rentals across all vehicle segments, rather than relying solely on OEM schemes. Such a scheme can prioritise domestically manufactured battery packs for commercial/goods vehicles, where the assembled cost of the battery pack is repaid by the consumer as a loan at a fixed rate. This will greatly reduce the CAPEX burden for the consumer and generate revenue for the government.

- **Establishment of LNG corridors:** Figure 9 and Figure 12 show that LNG-powered buses and trucks currently have the lowest TCO in their respective segments. This gas can be priced lower than CNG, as it can be distributed and sold by the LNG import terminals or third-party providers without passing through city gas distribution companies that charge additional margins and cascading taxes. In states that have access to LNG terminals, LNG refuelling stations can be established along key highways that have regular movement of buses and trucks. The government must revise and upkeep its target for deployment and operation of LNG stations and come up with standardised guidelines and regulations on setting up and operating LNG stations, and for selling LNG.

- **Data generation and transparency on running costs**: We found it unclear whether typical running and maintenance costs for EVs and hydrogen vehicles will be lower or higher than their petrol/diesel/CNG counterparts, as there have been no large-scale public trials to confirm the operating and maintenance costs, especially in the heavy duty segments. Annual maintenance costs play a significant role in the TCO of heavy duty vehicles, which typically have high annual mileage and wear-and-tear.

  The government can empower leading institutions like the Indian Institutes of Technology, along with the Automotive Research Association of India (ARAI), to carry out public trials of diesel, CNG, EV, and H_2 buses and trucks on a comparative basis over a period of one year to generate data on maintenance costs, fuel efficiency, performance, etc., to better understand the status quo and avenues of improvements.

  Data on maintenance costs can be made publicly available, at least for public e-buses operated under the GCC model in many cities. Under this model, the transit authority pays a fixed fee to a private operator for running public transport services. To improve transparency, state transport corporations and OEMs can provide operations and maintenance cost data by providing a breakdown of the GCC tariffs used. State transport authorities can also furnish running cost data on an annual basis for their diesel, CNG, and electric bus fleets separately, thus enhancing the quality and reliability of data available for researchers, policymakers and consumers.

- **R&D on emerging technologies for M&HGVs**: EVs are less competitive in the M&HGV segment, primarily because of limitations in battery range and extended recharging times. To enhance their competitiveness in this segment, more research efforts are required to improve energy density and reduce charging durations. Additionally, research efforts should also prioritise exploring diverse and advanced battery chemistries to support this transition.

  While EVs are likely to become the cleaner and more cost-effective choice for short- and medium-distance routes in the near future, this may not be as practical for long-distance routes. These routes often require multiple stoppages, and without significant improvements in charging durations, EVs might not be a viable option. Hydrogen FCEVs present a solution for this segment, offering refuelling times comparable to diesel while eliminating tailpipe emissions. However, hydrogen FCEV trucks are currently six times more expensive than diesel trucks. As shown in Figure 12, hydrogen FCEVs are projected to become competitive by the early 2040s. Therefore, parallel research efforts are required to accelerate this transition and realise the potential of hydrogen in long-haul transportation.

Acronyms

TCO	total cost of ownership
GST	Goods and Services Tax
CNG	compressed natural gas
LNG	liquefied natural gas
EV	electric vehicle
ICE	internal combustion engine
FCEV	fuel-cell electric vehicle
SUV	sports utility vehicle
LGV	light goods vehicle
MGV	medium goods vehicle
HGV	heavy goods vehicle
CAPEX	capital expenditure
NBFC	non-banking financial company
OEM	original equipment manufacturer
ARAI	Automotive Research Association of India
GCC	gross cost contract
SIAM	Society of Indian Automobile Manufacturers
CGD	city gas distribution
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
R&D	Research and development
GDP	gross domestic product

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