

Transitioning to a Low Carbon Technology for the Road Transport in India

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1. INTRODUCTION

It is an undeniable fact that the transport sector in India is one of the rapid growing sectors contributing around 6.7% in the GDP and the share is expected to reach at 12% by 2026.¹ The road transport forms a strong backbone of the transport sector in the country. In the FY 2019, the road transport alone contributed 67% of the total national and transport GVA correspondingly as presented in Figure 1.

In 2017, the total registered vehicles in India was estimated to be 253.3 million² and India ranked 8th highest in the world among 192 countries with the USA and China in the lead as explicated in Figure 2 (NITI Aayog). Even though it is among the top 10 nations in correspondence to the total number of vehicles in use, the total vehicle penetration per thousand population is far less when compared to major developed and developing nations presented in Figure 3.

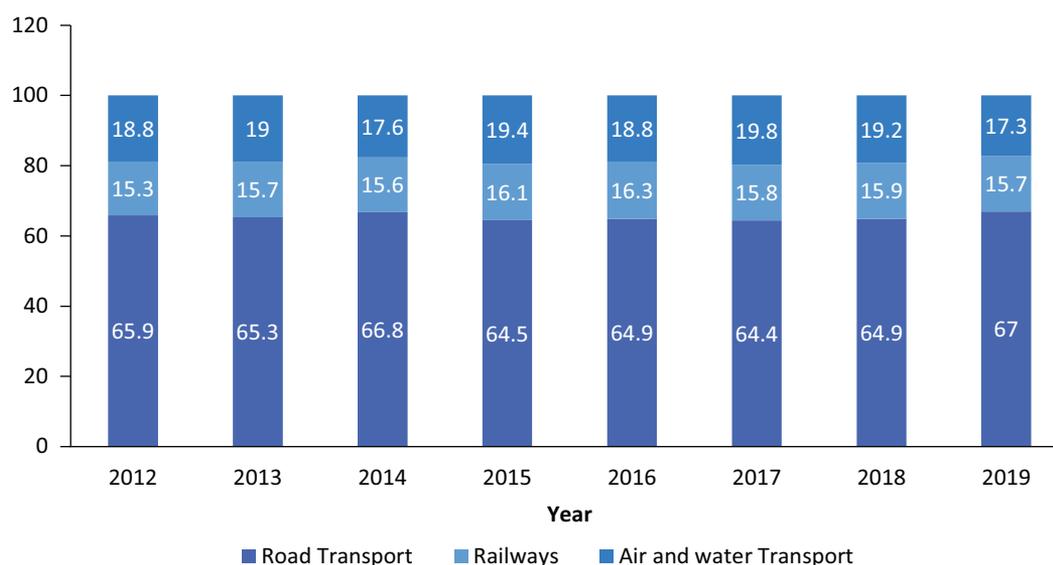


Figure 1: Gross value added: Transport sector

Source: NITI Aayog

¹ https://niti.gov.in/planningcommission.gov.in/docs/aboutus/committee/wrkgrp11/wg11_roadtpt.pdf

² <https://morth.nic.in/sites/default/files/Road%20Transport%20Year%20Book%202016-17.pdf>

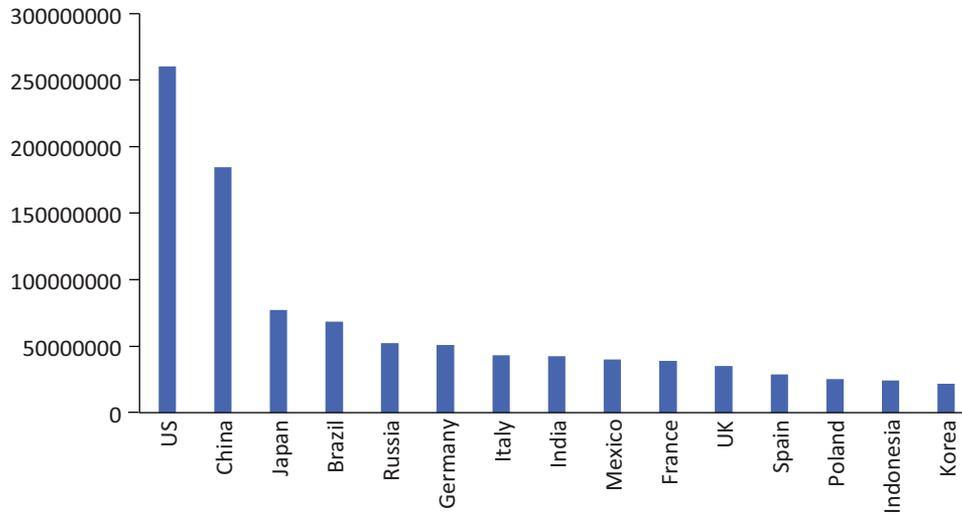


Figure 2: Total vehicles in use in the world

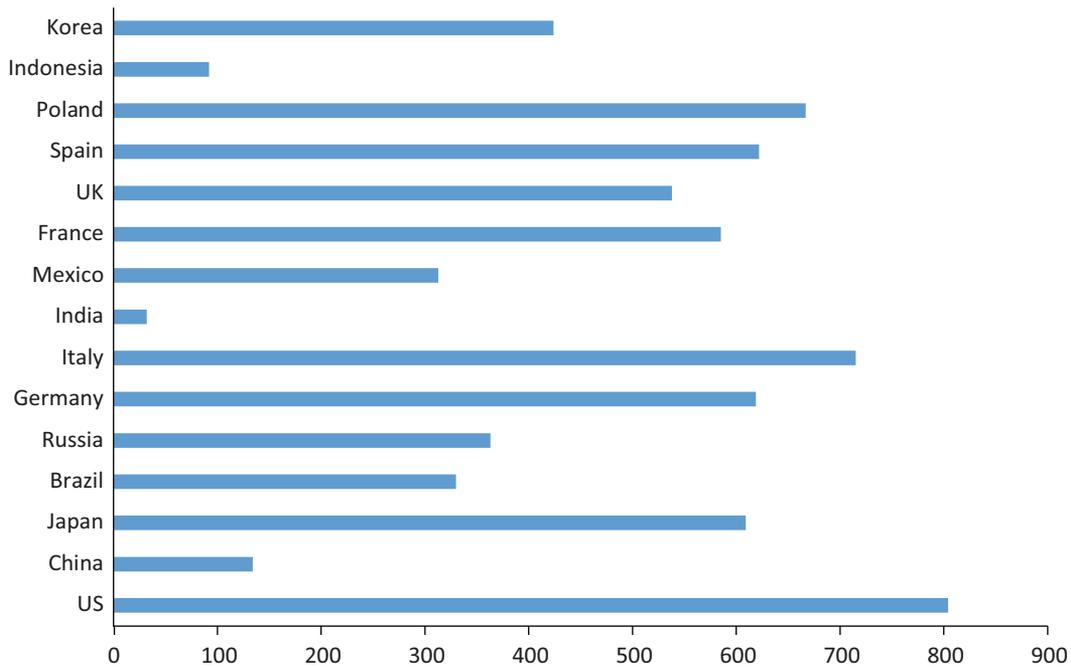


Figure 3: Total vehicle penetration per thousand people

Source: Ministry of Road Transport and Highways

The vehicle population in the country, growing at a fixed rate between 8 and 10% annually, is currently around 22 crore of which the 2-wheelers account for 74% and passenger cars around 12% of the total share. With the current rate of urbanization, rising purchasing power of individuals and favourable macroeconomics

and demographic trends, the prospective of the automobile sector is ascending in the Indian market. The automobile industry is expected to become a 300-billion-dollar market by the end of 2026 and will be emerging as world's third-largest passenger vehicle market by this year (Invest India). In addition, the nation has the largest

road network only after the US with 63.86 lakh km of rural-urban roads and national-state highways, with the national highways recording a compound annual growth rate (CAGR) of 7.25% followed by 6.25% of growth by rural roads and 4.27% by urban roads (Economic Survey 2020–21). Further to this, the highways and roads have forecasted to exhibit a CAGR of 36.16% between 2016 and 2025. Considering that around 65% of the total freight and 90% of total passenger traffic is carried by roads (Bhatnagar & Harshita, 2019) which is increasing significantly, it is a critical need for India to develop a well-built, connected, and optimized road segment nationwide.

The other important consideration is the rising high demand for generation of primary and secondary source of energy that will emerge in this sector in the future. The transport sector currently accounts for 10% of the total energy consumption in India with the sub-sector accounting for 90% of passenger and 67% of freight movement (MoRTH, 2016). Within the total petrol and diesel production in the country, 90% and 70% of the total consumption is diverted towards the transport sector, respectively. A large part of the diesel consumption is by the buses and the heavy-duty vehicle segments—almost 39%, while passenger vehicles (cars and utility vehicles)

account about 22%. Population and urbanization are considered as strong propeller contributing to the increasing energy demand in this specific sector.

As per India’s third Biennial Update Report to the UNFCCC (submitted in February 2021), the energy sector contributed 75.01% of the total CO₂ emissions in 2016, within which the highest share was from the electricity production (39.53%) followed by manufacturing industries and construction sector and 13% from the transport sector (9% from the road transport).

In a collaborative assessment conducted by Shakti Sustainable Energy Foundation (SSEF) and TERI,⁴ it has been suggested that an integrated multi-pronged approach is crucial towards decarbonizing the transport sector in India wherein increased fuel efficiency, fleet modernization and modal shifts were considered as the low hanging fruits for the transition to low carbon economy. The Government of India has already introduced various policies and schemes to promote reduction of emissions and sustainable development in this sector, which now would require significant efforts and push for the implementation process, which is imperative to achieve a just transition clean energy future.

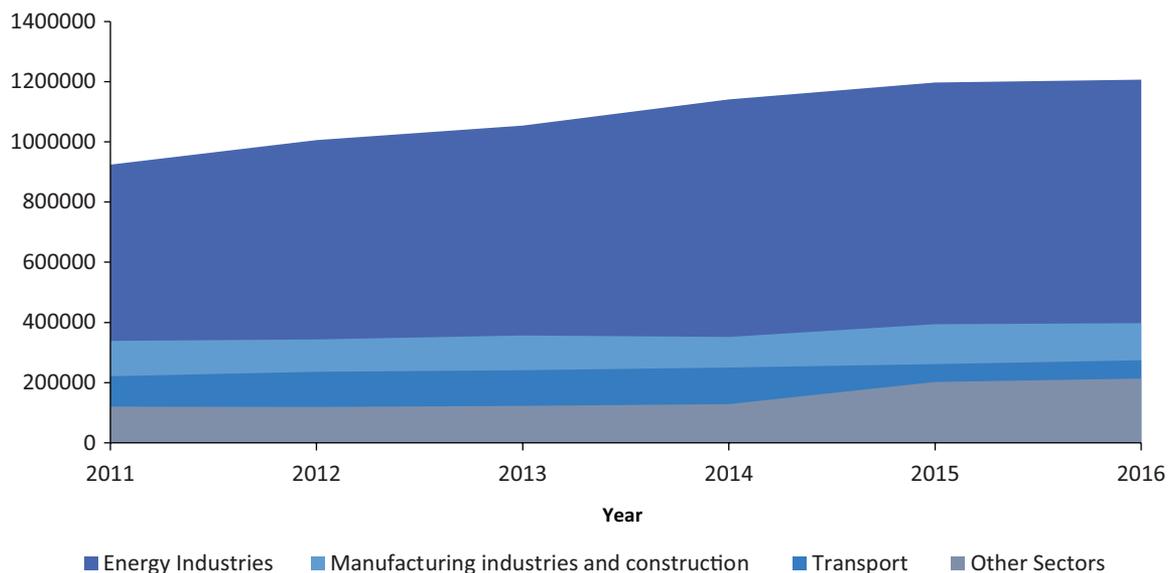


Figure 4: CO₂ emissions from the energy sector

Source: Third Biennial Update Report (BUR), MoEFCC

³ https://shaktifoundation.in/wp-content/uploads/2019/11/Intermodel-Study_Final-Report.pdf

This paper is an attempt to understand the current policy landscape of the Indian transport sector and its plans to transition to a sustainable growth paradigm through assessing the energy demand and emissions in the long-term scenario. The assessment is done through development of a comprehensive road transport model, which takes each of the vehicle segments and technology types into account under the broad categories of passenger and freight vehicles. Accordingly, depending upon the technology penetration, the gaps and barriers are highlighted along with a line of recommendations to overcome the challenges for a low carbon development of the transport sector in India.

2. Policy Landscape of the Transport Sector in India

As part of its Nationally Determined Contributions (NDCs), India has committed that the country will reduce the emissions intensity of its GDP by 33–35% by 2030 as compared to 2005 level and to create an additional carbon sink of 2.5–3 billion tonnes of CO₂

equivalent through additional forest and tree cover by 2030. The growing economic and environmental burden of transport activity and driven by commitment under NDCs, the government has taken numerous steps towards mitigating the transport-related externalities and shifting towards low carbon transport. Some of these steps are discussed below:

The **National Electric Mobility Plan (NEMMP 2020)** was launched in 2013 with the chief objective of promoting hybrid and electric vehicles (EVs) in the country and reducing the sole dependence on the imported oil and introduce cleaner fuel technologies in the transport sector. The main target was set to introduce 6–7 million units by 2020 including targeted category of the two-wheeler (2W), three-wheeler (3W), four-wheeler (4W), buses, and light commercial vehicle (LCV) segments. As part of the NEMMP 2020, the Faster Adoption and Manufacturing of (Hybrid &) Electric vehicles (FAME) scheme was launched in 2015 to promote manufacturing of the electric and hybrid technology. The scheme essentially focuses on the four main areas of the technology development, demand creation, pilot projects, and charging infrastructure. In

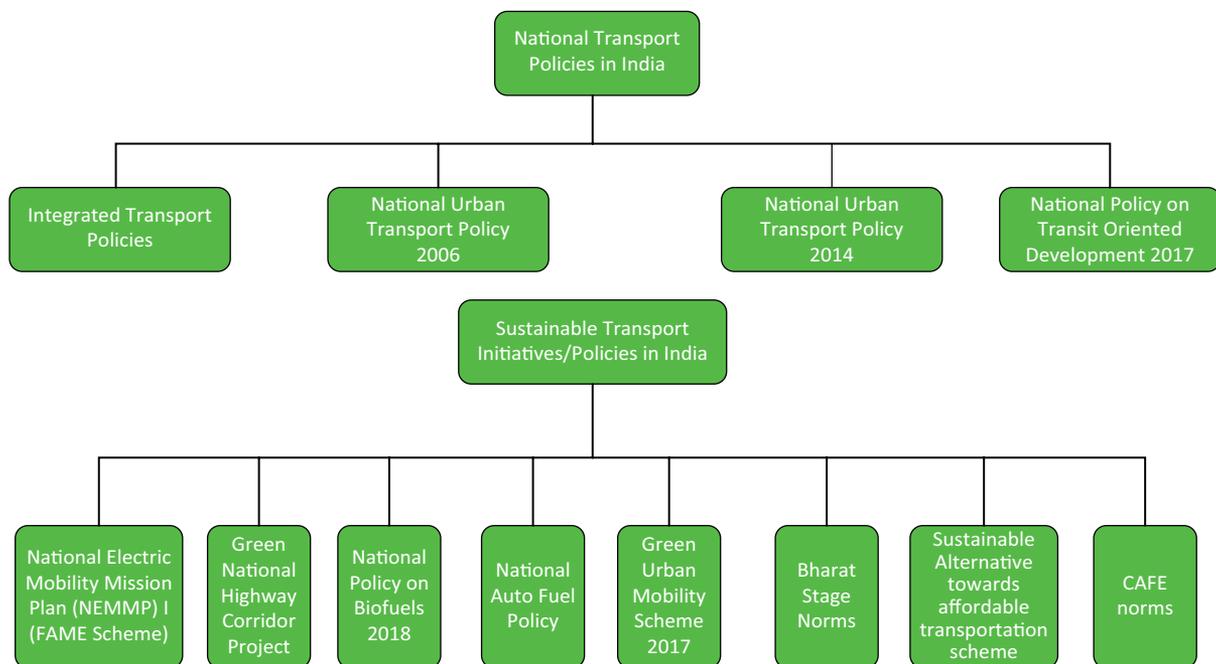


Figure 5: Landscape of India's transport policies

Source: Authors' compilation AS2

pursuance to encourage the commercialization and EV roll out in India the focus was entirely on the market creation through incentivizing all the vehicle segments including 2W, 3W (auto), passenger 4W vehicles, LCVs, and buses. In the 1st phase of the scheme, the total budget that was allocated was estimated to be around ₹ 529 crore and about 2.78 lakh EVs were supported with a total demand incentive of ₹ 343 crore (approx.). In addition, 465 buses were sanctioned to various cities/states under this scheme¹.

The first phase of the scheme was for two years (2015–17), which entirely focused on the coordination between urban planning, transportation, and power sector for systematic adoption of EVs in the country. The scheme was further extended as the second phase for the period of three years commencing from 2019 with an allocated budget of ₹10,000 crore, of which 86% funds were allocated for demand generation in the public transport sector. This phase aims to generate demand by way of supporting 7000 e-buses, 5 lakh e-3W, 55,000 e-4W passenger cars (including strong hybrid) and 10 lakh e-2W. As on June 2021, the total number of vehicles sold were around 133,831 with an estimated impact of 4.2 million kg CO₂ emission reduction, which marks 4.25% target completion of the FAME II scheme in India. The Government has also planned to roll out 30% of EVs in India by 2030. India is also a part of the Electric Vehicles Initiative (EVI), a multi-government policy forum dedicated to accelerating the introduction and adoption of EVs worldwide.

The Government had set a target of reducing the oil dependency by 10% till 2022 targeting an import reduction from 77% (in 2014–15) to 67%. In order to further fulfil Prime Minister's vision to reduce import dependency in the oil and gas sector, the Government of India had earlier introduced the **National Policy on Biofuels** in 2009 and aimed for an ambitious blending of 20% biofuels in petrol and diesel till 2017. The Policy also envisaged to contribute towards a sustainable and clean transport system within the country. However, post 2017, the target could not be met due to high variability in the demand supply ratio of ethanol and biodiesel for blending purposes. The Policy was later revised in the year 2018 which followed a more practical approach based on the availability of domestic feedstock and potential for drop in and advanced biofuels targeting 20% of ethanol

and 5% of biodiesel blending till 2030. Recently, the Ministry of Petroleum and Natural Gas (MoPNG) has laid out a target for 10% ethanol blending of gasoline fuel all over the country by April, 2022. In addition to this, the MoPNG/the Ministry of Road Transport and Highways (MoRTH) discussions with auto industry is to achieve uniform blending of 10% ethanol in gasoline by 2022 and mandate 20% ethanol blending w.e.f. April 2025 pan India.

Within the **National Auto Fuel Policy**, the Government of India finalized India's first light duty passenger vehicle fuel efficiency standards and is in the process of bringing out the norms for heavy duty vehicles. The Indian regulation 'Bharat Stage (BS)' norms follow the European Union regulatory pathways and are currently applicable for light duty passenger cars and commercial vehicles, heavy duty trucks, buses, and 2W. The continuous fuel efficiency reduction of dependence of oil, the norms also contribute to significant reduction of the air pollution in the high pollution cities in India. The widely known BSIII and BSIV fuel are being supplied in the country with a gradual transition to the latest BSVI norms in a Tier I city like Delhi. The leapfrog from BSIV to BSVI by 2020 for majority of vehicles is due to lagged implementation and high potential of emissions reduction under the latest norms. The fuel under the BSVI norms has to have the potent capacity to reduce one-third of the air pollution in vehicles and has 10 per million (ppm) sulphur along with a significant reduction of NO_x emissions by 25% in petrol and 70% in diesel cars.

Vehicle Fuel Efficiency Programme: In 2014, the Government of India (BEE) finalized India's first light duty passenger vehicle fuel efficiency norms (CAFÉ norms) and Phase 1 was implemented w.e.f. 2018 and more stringent Phase 2 CAFÉ norms are scheduled to be implemented from 2022. The MoRTH is also working with the industry for evolution of fuel efficiency norms for heavy duty vehicles. Continuous tightening of CAFÉ norms help conserve the fuel and reduce the CO₂ emissions.

The Green Urban Transport Scheme was introduced to develop and improve climate transport system in urban areas including metro rail, non-motorized transport with the main objective to reduce carbon emissions through innovative financing tools for the projects in cities where the population is over 5 lakh and above including all capital cities.

The **Green Urban Mobility Scheme** would promote the use of hybrid/EVs and non-fossil fuels among others for public transport in 103 cities that has more than 5 lakh population.

The **Green National Highways Corridor** project comprises of development of eco-friendly National highways, which accounts for 2% of the total road length in India. In addition to this, in 2018, the Sustainable Alternative towards Affordable Transportation (SATAT) scheme was launched with the aim to increase the production of compressed biogas from waste/biomass sources such as agriculture residue, cattle dung, sugarcane press mud, municipal solid waste, sewage treatment plant waste, etc., as a transportation fuel.

The opportunities in technological transformation to transition to clean energy is very limited in the world and is mainly influenced by solar and wind and non-lithium-ion batteries. However, over the years with technological advancements and efficiency improvements the cost of operating has been substantially driven down especially in the case of lithium-ion batteries (-84%) and solar (-87%) (TERI, 2020⁴). The progress in the electrification of the commercial passenger vehicles has picked up in majority of states such as Uttar Pradesh (29%) and

Delhi (11.8%) in India (CEEW). In the recent years, fuel cell electric vehicles (FCEV) have witnessed significant growth have picked up, which are hydrogen-based cells that hold higher conversion efficiency and have the potential to charge within 5–15 minutes, as compared to battery electric vehicles (BEV), which on average take 90 minutes. All things considered, the feasibility of green and blue hydrogen and market entry of the technology is highly unlikely in the near future considering the higher upfront costs and the pace of development associated with it. However, taking into account the high potential associated with hydrogen technology in reducing the carbon intensity, it is essential to assess the long-term impact of the different drivetrain and technologies in order to divert the clean energy production in the right direction especially for a developing nation like India. Apart from policies and regulations, there are a number of factors that determine the natural pace and direction of vehicle transition in India. Some of those are vehicle economics (total cost of vehicle ownership), fuelling infrastructure, time, user acceptability, etc. These were studied comprehensively in the TERI report 'The potential role of hydrogen in India', published in 2020. Some of the key conclusions from the report are tabulated below.

Table 1: Summary of factors influencing the road transport transition

	Diesel	CNG/LNG	Electric	Hydrogen
TCO	No longer competitive post 2030	Already competitive to diesel, Electric and Hydrogen to compete post 2030	Competitive across all distances post 2030	Competitive over longer distances
Refuel/charging time	15 mins	15 mins	2 hrs+	15 mins
Infrastructure requirements	Already in place	CNG stations are required. New LNG stations required	New high capacity charging network required	New hydrogen refuelling stations required
User acceptability	No change	Minimal change	Change to fleet operation required	Minimal change required
Weight penalty	No change	Minimal	Significant for long distance but will reduce	Minimal

Source: Author's analysis

⁴ MAKE HYDROGEN IN INDIA, Driving India towards the clean energy technology frontier, <https://www.teriin.org/sites/default/files/2020-06/Hydrogen-Policy-Brief.pdf>

3. Transport Sector - Demand Modelling

To foresee the possible impact of road transport decarbonization in energy and emissions in 2050, we have modelled 'plausible' scenarios assuming different levels of technology transition. The scenario framework, assumptions, and results are discussed in the subsequent section.

3.1 Scenario framework

Firstly, we categorized the vehicle segments broadly into two: 1) passenger, which includes two-/three-/four-wheelers and bus segments, and 2) freight, which includes light duty and heavy-duty vehicle segments. For the easiness of modelling, we consider three- and four- wheelers, inter-city and intra-city bus, and light duty trucks and heavy duty trucks as one. Further, three scenarios were framed to represent possible vehicle technology transitions to BEVs, FCEVs, and natural gas vehicles (NGVs) from petroleum fuel-based vehicles. These scenarios are named as 'Baseline', 'Moderate' and 'High' ambition scenarios. The assumptions considered for each of the scenarios are briefed below.

Baseline ambition scenario: This scenario represents a baseline view of technology transition levels, especially

to BEVs and FCEVs in passenger and freight vehicles to 2050. However, for NGVs, as they are already competitive, we considered comparably high transition levels.

Moderate ambition scenario: In this scenario, we consider moderately ambitious level of technology transition. In case of two-, three-, four-wheelers, short haul bus segments and light duty trucks, we assume that the transition would be favoured to BEVs and for long haul buses and heavy duty trucks; it would be to FCEVs in the long term. We also assume the negative impact on NGV transition across segments due to aggressive penetration of BEVs and FCEVs.

High ambition scenarios: As the name suggests, this scenario imagines a very high technology transition level to zero carbon technologies such as BEVs and FCEVs to 2050. Here, we assumed, the BEVs and FECVs would co-exist, especially in long haul buses and freight segments due to the improvements in battery chemistries. This is expected to negatively impact the NGV transition in the long term, in a much higher level than in other scenarios.

The detailed assumptions are tabulated in Table 2.

Table 2: Assumption on penetration of new energy vehicles in yearly sales

Segments	Year	Scenario	Penetration rate of various vehicular technologies (%)		
			Battery electric vehicles	Hydrogen based vehicles	Natural gas vehicles
Two-wheelers	2030	Baseline Scenario	14%	-	-
		Moderate Ambition Scenario	17%	-	-
		High Ambition Scenario	22%	-	-
	2050	Baseline Scenario	60%	-	-
		Moderate Ambition Scenario	75%	-	-
		High Ambition Scenario	90%	-	-
Three-/Four-wheelers	2030	Baseline Scenario	11%	-	23%
		Moderate Ambition Scenario	14%	-	23%
		High Ambition Scenario	21%	-	22%
	2050	Baseline Scenario	50%	-	35%
		Moderate Ambition Scenario	60%	-	30%
		High Ambition Scenario	85%	-	5%

Table 2: Assumption on penetration of new energy vehicles in yearly sales

Segments	Year	Scenario	Penetration rate of various vehicular technologies (%)		
			Battery electric vehicles	Hydrogen based vehicles	Natural gas vehicles
Buses	2030	Baseline Scenario	8%	1%	28%
		Moderate Ambition Scenario	15%	1%	28%
		High Ambition Scenario	13%	1%	28%
	2050	Baseline Scenario	30%	20%	30%
		Moderate Ambition Scenario	50%	20%	20%
		High Ambition Scenario	60%	25%	10%
Trucks	2030	Baseline Scenario	9%	0%	22%
		Moderate Ambition Scenario	11%	1%	23%
		High Ambition Scenario	14%	1%	24%
	2050	Baseline Scenario	35%	20%	30%
		Moderate Ambition Scenario	40%	30%	20%
		High Ambition Scenario	50%	30%	11%

Source: TERI assumption based on expert consultation

Apart from the stock ownership growth assumed for each of the vehicle categories, the other key parameters considered are annual vehicle kilometres and lifetime of vehicles. Depending on the technology types, vehicle mileage and energy efficiency improvements were also assumed. These assumptions are briefed in the subsequent sections.

3.2 Stock growth assumptions

The historic vehicle stocks for each of the segments have been gathered through literature review. Further, the vehicle stock growth for each of the segment is assumed based on the cross-country learnings and expert consultations. For instance, we assumed that the stock growth ownership for two-wheeler ownership is

expected to rise faster, from 117 per 1000 population in 2015 to 302 per 1000 population by 2050, driven by the relative affordability and traffic density aspects. Similarly, the four-wheeler ownership in India is expected to grow from the present 21 cars per 1000 population in 2015 to 127 cars per 1000 population by 2050. This is of the view that the rate of four-wheeler ownership in India is still far less than in developed countries. In case of bus segment, we assumed that it would grow from the present 1.6 to 3 buses⁵ per 1000 population driven by the strong policy push towards encouraging public transportation, improving infrastructure and connectivity between rural and urban areas, etc. In case of freight⁶ transportation, we assumed the stock growth to rise to 37 vehicles per 1000 population driven by the policies driving industrialization.

⁵ Comprising inter-city and intra-city buses

⁶ Comprising heavy duty and light duty trucks

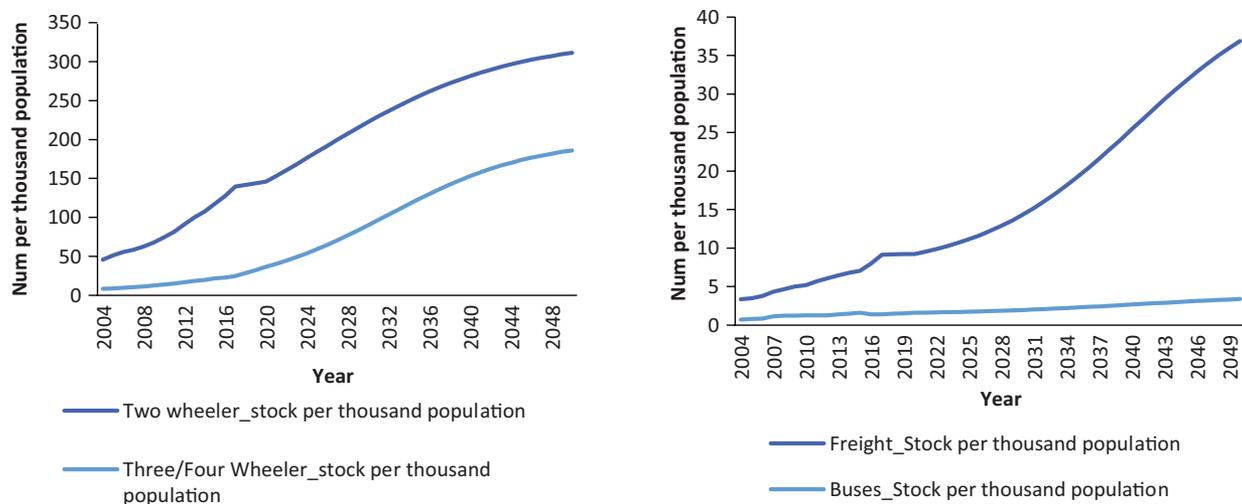


Figure 6: Vehicle stock growth assumption for passenger and freight segments

Source: TERI analysis based on expert consultation

3.3 Operational parameters and assumptions

The assumptions around operating parameters typically vary based on vehicle technology and application. These assumptions were made based on extensive literature review, and validated through consultation with in-house experts. The assumptions are detailed in Table 3.

Emission factor

The emission factor considered for conventional fuels and natural gas are based on IPCC Emissions factor database. The emission intensity projection of grid electricity is taken from IEA projections. This is estimated under sustainable development scenario assuming aggressive

Table 3: Operational parameters and assumptions

Segments	Life time	Annual distance travelled ^{7,8,9}	Occupancy	Specific fuel consumption [Petrol/Diesel]	NGVs	BEV	FCEV
Unit	Years	km	No. of passengers	km/l	kWh/100 km	kWh/100 km	kWh/100 km
Two-wheelers	8	8,830	1.5	45.45	-	6	-
Three-/Four-Wheelers	10	20,000	2.5	16.66	48	17	-
Buses	15	72,600	25	6.6	350	120	200
Trucks	15	107,250	9	6.6	260	70	210

Source: TERI analysis¹⁰

⁷ <https://unepdtu.org/wp-content/uploads/2014/08/assessment-of-motor-vehicle-use-characteristics-in-three-indian-cities.pdf>

⁸ https://morth.nic.in/sites/default/files/srtucopy_compressed.pdf

⁹ <https://morth.nic.in/sites/default/files/File2842.pdf>

¹⁰ <https://www.iea.org/reports/etp-model-2017>

de-carbonization of Indian power sector in 2050. For hydrogen, we have considered that all of it will be produced using 'green' electricity and so, no emissions.

Key assumptions

- It is assumed that all vehicle segments are operating 330 days yearly for the estimation of annual distance travelled.
- It is assumed that the technology transition in the three-wheeler and four-wheeler segments would be similar and, therefore, these two segments have been combined for the modelling projections.
- The bus segment includes both inter and intra-city buses and the analysis does not consider the technology penetration in each of these sub-segments to avoid complexity with the computation model.

3.4 Modelling methodology

In order to assess the energy demand and emission in such long terms, we have developed a comprehensive road transport model. This takes each of the segments and technology types into account under the broad categories

of passenger and freight vehicles. Further, vehicles stocks projected for each of the segments are decomposed to see the yearly new sales and replacement of retired vehicles to 2050. Thereafter, the assessed new yearly sales for each of segments are further disaggregated based on the assumptions of percentage penetration by technology types. This stocks composition by technology types in each of the segment along with useful lifetime, respective mileage to see the energy consumption. Further, through multiplying energy source-wise demand with respective emission factors helped to see the overall emissions from the road transport sector.

3.5 Results and discussion

The results suggest that the total passenger road transport activity would increase by four times between now and 2050, reaching from 9,083 in 2018 to 36,374 billion pkm. This growth is to be driven strongly by four-wheelers and bus segments in particular. On the other hand, the freight transport activity is expected to increase by 5 times in the same assessment period, reaching out to 52,482 billion Tkm from 10,652 BTkm by 2050 presented in Figure 7.

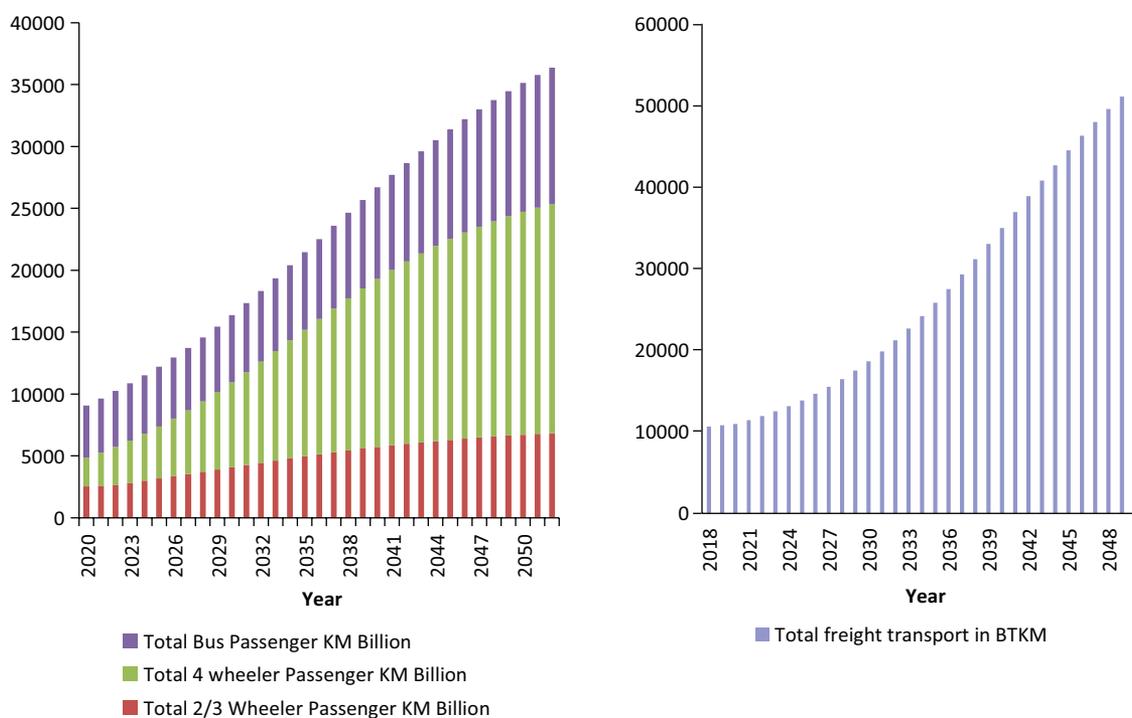


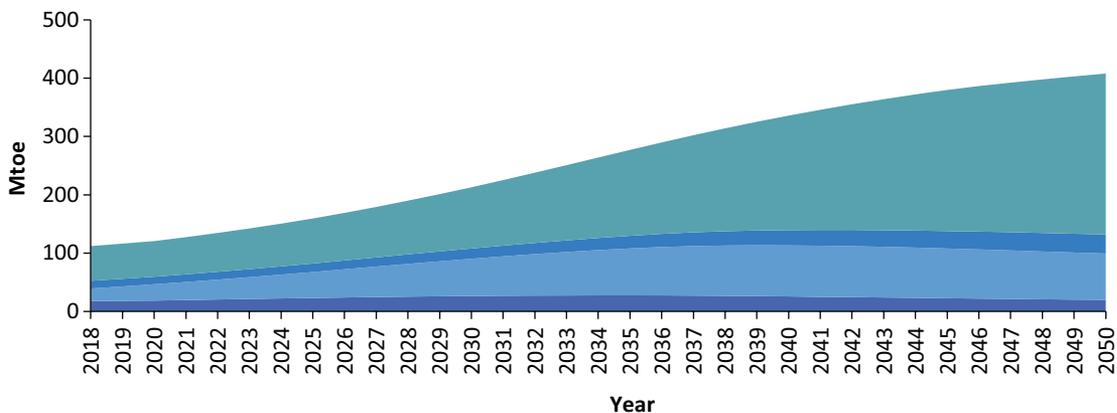
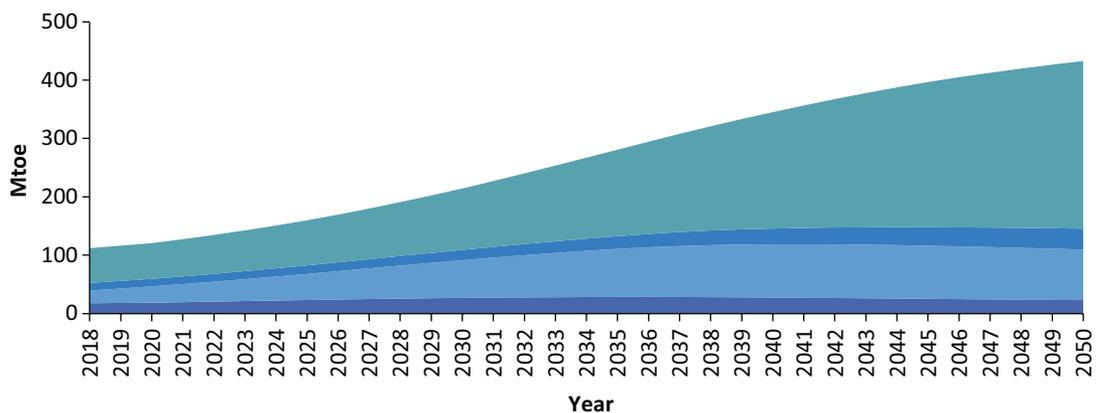
Figure 7: Projection of total passenger and freight activity to 2050

Source: TERI analysis

This strong transport activity in passenger and freight segments suggests that the energy consumption will drastically rise in future. However, the magnitude of demand increase is based on the technology types penetrated in respective segments. This is discussed here.

We see that the energy demand for transport activity would increase by two times from present level of ~271 Mtoe in various scenarios of vehicle technology transition. In a baseline penetration scenario, the total energy requirement is reaching out to 432 Mtoe whereas, in a moderate and high ambition scenario, the same is seen to be lowered by 10% (383 Mtoe) and 22% (294 Mtoe), respectively (Figure 8). Hence, it is evident that the entire transport system is becoming more efficient as a result of a technology transition to battery and fuel cell-based vehicles. Now, while looking segment-wise, freight segment in particular is driving the growth in petroleum fuel-based energy consumption. This is majorly due to the

lack of alternate feasible technology options, relatively high useful time, and higher activity levels of freight vehicles. This is clearly visible in a baseline scenario where petroleum based-energy demand is suggested to be ~67% of the total requirement by 2050 (Figure 8). While imagining a moderate to high level of new energy vehicle penetration in a scenario, the demand of petroleum-based fuels are seen to reduce by 16% and 40% from baseline demand level. This is attributed to the deepened transition in various 'hard to abate' road transport segments. On the other side, the electricity energy demand is expected to grow significantly in moderate and high ambitious scenario, reaching out to 152 Mtoe, and 233 Mtoe by 2050 (Figure 9). The natural gas would potentially act as a 'bridge fuel' for decarbonizing transport sector, replacing petroleum fuel-based vehicles from four-wheeler, bus and freight segments. The demand is expected to reach 463 Mtoe and 316 Mtoe in moderate and high ambition scenarios, respectively, by 2050.



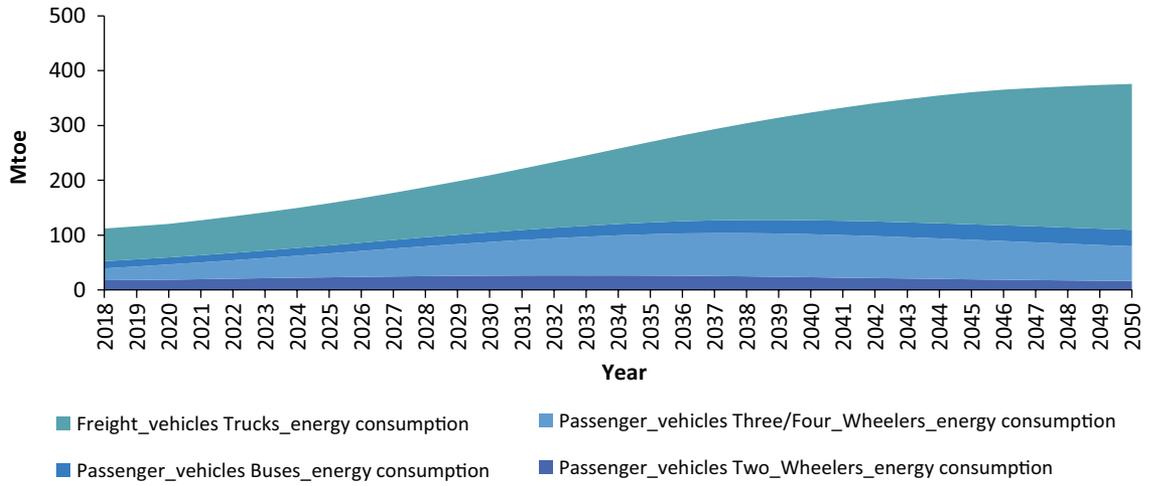
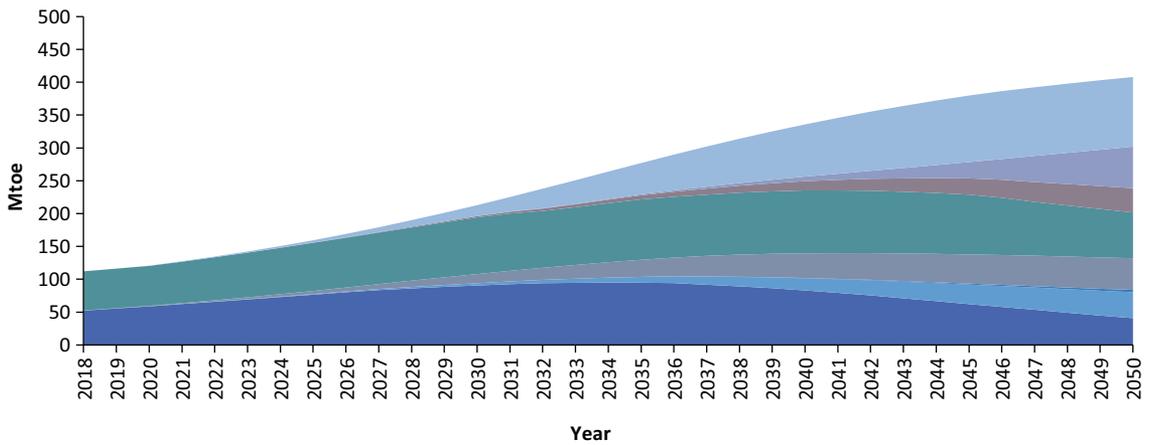
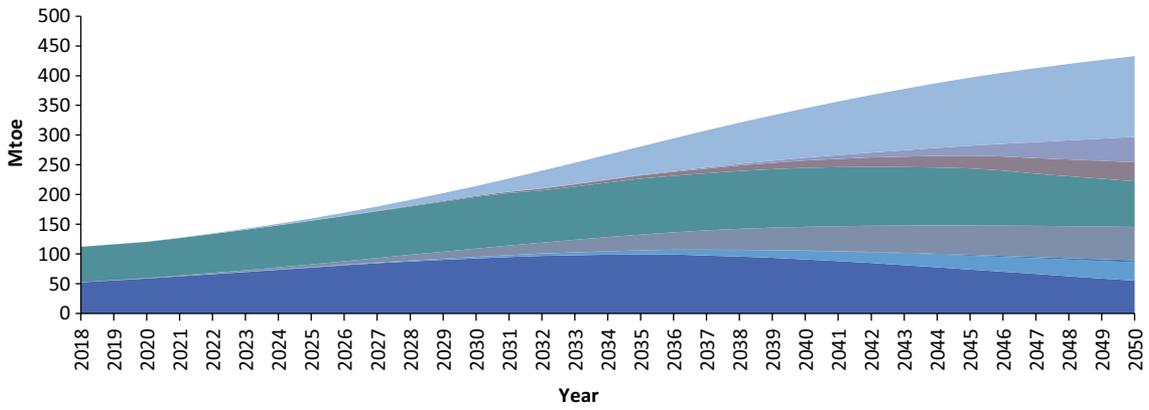


Figure 8: Share of total energy consumption by different segments in baseline, moderate and high ambition scenario (in Mtoe)

Source: TERI analysis



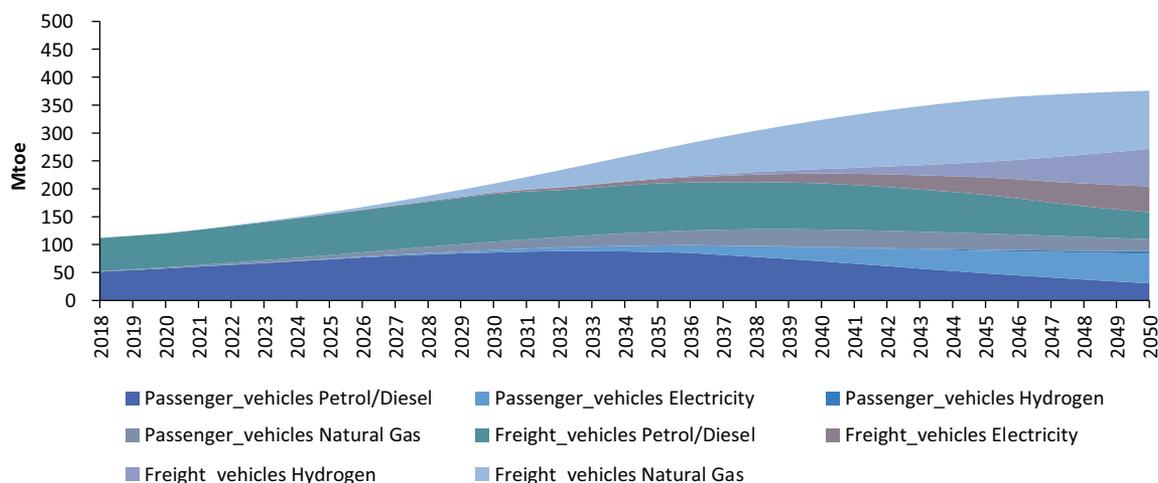


Figure 9: Source-wise energy consumption for passenger and freight segment in baseline, moderate ambitious, and high ambitious scenario (Mtoe)

Source: TERI analysis

Though, the transitioning to BEVs and FCEVs results in both energy efficiency improvement and use of cleaner fuel it doesn't directly mean that the overall emissions will reduce. In order words, reduction in fossil fuel use from BAU scenario is inevitable and this will bring down GHG emissions; however, there will be increased use of electricity due to increased share of EVs, which will increase the GHG emissions. Therefore, the net effect will depend on GHG intensity of the electricity used by electric vehicles. It is because; the emissions are completely dependent on production method of energy source. This is evident in this study, which suggests an emission reduction to the extent of 10% and 18% from baseline scenario can be achieved by 2050 in a moderate and highly ambitious scenarios while using grid electricity¹¹ whereas the mitigation extent would be much greater, in the range of 18% to 37%, if electricity is being directly sourced from zero carbon generation sources such as renewables, hydro, etc. In both cases, the potential role of BEVs and FCEVs for achieving early net-zero is evident, much sooner if using cleaner source of electricity.

Some of the key takeaways from the study are listed below:

- Demand for road transport is expected to grow exponentially till 2050:** Passenger activity is estimated to increase by four times—from around 9,083 Bpkm in 2018 to 36,374 Bpkm in 2050. The freight activity is expected to grow at a much faster rate, by 12 times—increases from 10,652 BTKM to 52,482 BTKM during the same period.
- Technology transition could lead to high energy savings and emission benefits in long term:** The transition to EVs and hydrogen fuel cell will result in large energy savings, depending on penetration levels. In this study, we find that the resulted energy savings are in the order of 6.5%-13% compared to a baseline scenario, in different scenarios. Also, as the grid decarbonizes, the transport emission peaks early and subsequently will have a steep fall due to the increasing share of EVs and FCEVs in the total road transport energy mix. We analyse that emission reduction to the extent of 10% and 18% compared to

¹¹ Emission intensity (gCO₂/kWh) of grid electricity is assumed to decline drastically to 2050, reaching out to 298 gCO₂/kWh from the present level of 800g CO₂/kWh as the grid electricity decarbonizes

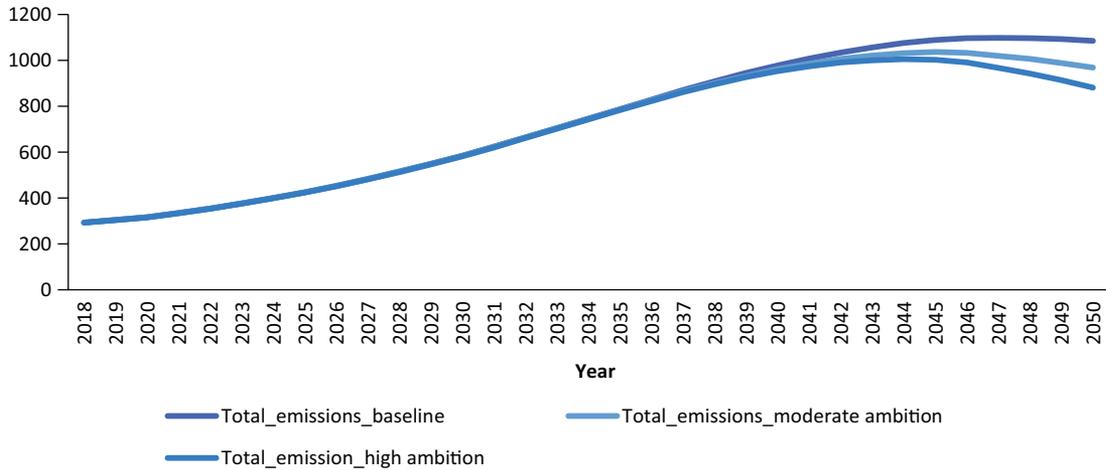


Figure 10: Total CO₂ emissions from road transport in baseline, moderate, and high ambition scenarios; electricity from grid

Source: TERI analysis

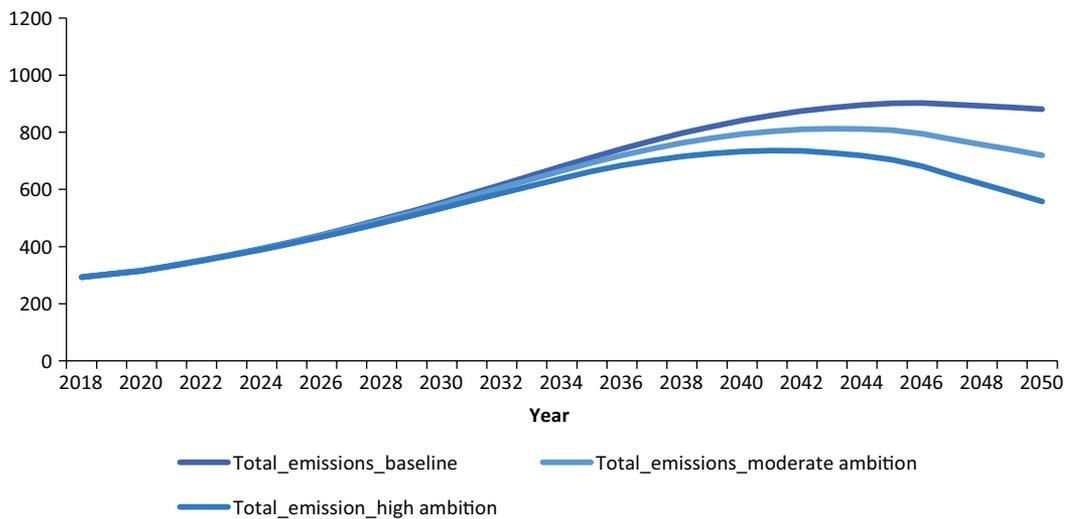


Figure 11: Total CO₂ emissions from road transport in baseline, moderate, and high ambition scenarios, electricity from clean sources

baseline scenario can be achieved by 2050 in moderate and highly ambitious scenarios even while using grid electricity. However, this could be much larger, in the range of 18%–37% if sourced from zero carbon electricity sources.

- **Achieving deep decarbonization depends on identifying and developing solutions in vehicle segments where electrification possesses limitations:** Electrification is not a panacea, especially due to its high battery cost and gravimetric energy density. Therefore, it is expected to penetrate more in

short haul passenger segments. Hence, long and heavy duty buses and freight segments are termed as ‘hard to abate’ segments in transport. The only emerging zero carbon solution for this segment is green hydrogen. However, it not very much clear how it is going to flourish in this sector. Deep-decarbonization depends on identifying the challenges, and developing green hydrogen vertical through integrated development of low carbon infrastructure and through policies and mandates.

- **Fast-paced development of integrated low carbon infrastructure is crucial for faster transition:**

Integrated low carbon infrastructure development in a fast manner is crucial for increasing the access and thus, for the large-scale adoption. For EVs, most of the infrastructure is already available. The only need is to upgrade the grid infrastructure for supporting increasing demand and increase the access to charging infrastructure. However, for hydrogen, an integrated value chain needs to be created to enable the transition in 'hard to abate' sectors. This needs holistic planning and investment that supports the development of hydrogen infrastructure. Much before, it needs long-term policies and mandates that paves the investments pathway.

- **Operating lifetime of vehicles are crucial for achieving net-zero transport sector:**

Even in a high technology transition scenario, we saw that the residual conventional vehicles entered into the system stays there till the end of its operational life, which is quite long in case of buses and freight segments. This slows down the pace of fleet modernization and technology transition and the ultimate target to achieve a high efficient and net-zero transport system. Hence, there is a need to revisit to determine the actual operating life of vehicles, which creates a win-win situation for both, the consumer and environment.

4. Way forward

Alternative Fuels/Fuel Switching

The pragmatic way for India to gradually evolve and transition towards a clean energy economy is by incorporating a mix of clean energy alternatives, which are feasible and economical. Natural gas and biofuels have been identified as major alternative to low-emitting fuels in India.

Biofuels

In order to meet the 20% biofuel blending target there would be a requirement of a push from the government mainly via policy instruments such as mandates, financial

incentives, and a carbon value at both production and distribution chains. In addition to this, the scaling of biofuels in India to meet the National target for 20% blending would require additional collaborative efforts and take off agreements between private and government players to bridge the current demand and supply gap via exploring other potential streams of feedstocks and funding to set up infrastructure.

Electric Vehicles

The market share of electric vehicles in India is expanding, however, there are still some existing technological, infrastructure and market barriers that persist in smooth implementation of EVs in India. The issues pertaining to charging infrastructure¹² and battery recycling requires long-term solutions. It is estimated that India requires around 4 lakh charging units to meet the requirement of 2 million EVs by 2026. Currently, there are 1800 units across India for approximately 16,200 cars.¹³ There is a need for ramping up the accessibility of the charging units and more critically optimization of vehicle to grid technology. In addition to this, providing vehicular maintenance services and raw materials for batteries primarily lithium and cobalt considering the estimated demand will increase by 10–20 times more than the current consumption. Lastly, it is crucial to focus on transitioning away from conventional heavy duty long distance modes of transport including buses and trucks, considering they are major source of public and goods transport for both inter and intra cities. The high capital costs and technological issues linked to this hard to abate segment within the transport sector require high funding and support in research and development.

A majority of consumers experience 'range anxiety' and are wary of the long distance journeys on the current battery capacity. Currently, most of the EVs operate at 400 Volts, however, recently the range capacity of these vehicles has been increased to 800 Volts through wiring up more battery cells in the current battery series increasing potential for reliability in distance.¹⁴

¹² Charging stations refer to high-power EVSE, typically Mode 3 or Mode 4 charging, often with multiple charging guns

¹³ https://www.business-standard.com/article/automobile/india-to-require-400-000-charging-stations-for-2-mn-evs-by-2026-report-121061200880_1.html

¹⁴ <https://www.economist.com/science-and-technology/new-800v-electric-cars-will-recharge-in-half-the-time/21803666>

Aside from technological renovation, financial incentives such as direct discounting, interest subventions, tax exceptions, removal of exemption fees, income tax benefit, scrapping incentive can play an instrumental role in driving up the demand of electric vehicles. New Zealand has introduced new rebates for plug in and hybrid electric vehicles along with additional costing on purchase of the high emitting vehicles. Tax bonuses are playing a critical role in this transition in countries like the US and Norway, while France and the UK Government are providing discounts/incentives on the sale of EVs.

Hydrogen

R&D support in hydrogen and fuel cell technologies: From the international experience, it is evident that green hydrogen can play a vital role in decarbonizing the vehicle segments where direct electrification poses limitation. However, there should be a greater focus on demonstrating hydrogen and fuel cell technologies, initially through pilots. This would help in providing an understanding on where the gaps are and what are

the challenges. Also, the government should support advanced fuel cell R&D programmes. This could be through international collaboration overseen by ministerial level committee. These help in achieving rapid cost reductions in hydrogen and fuel cell technologies to long term. Such activity would also align with the 'Make in India' and 'Atmanirbhar Bharat' initiatives.

Supporting creation of early hydrogen ecosystem: Government support through policies and regulations could give momentum to the hydrogen ecosystem creation. This could be through setting targets and mandates in transport sector to the long term. This gives adequate time for the automobile manufacturers to plan and prepare for the transition. Initially, state transport departments can drive this technology transition initiative—like for EVs. Further, financial incentives and credit support could further boost its adoption. Without clear financial benefits, the fragmented logistic operators who are running at lower margins are difficult to change.

