ROADMAP FOR INDIA'S ENERGY TRANSITION IN THE TRANSPORT SECTOR

EXECUTIVE SUMMARY

THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

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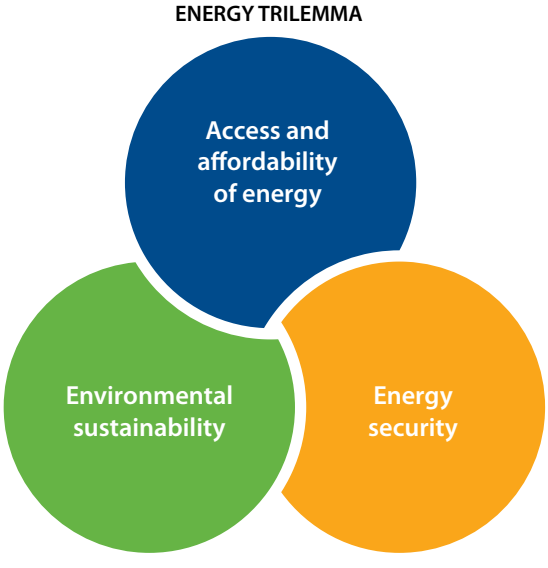
Introduction

Transport sector plays a crucial role in development of a nation, by providing access to public-space, essential services, and opening newer avenues of employment opportunities (direct and indirect). Railways for example have been pivotal in industrial revolution and associated economic prosperity. Despite the existence of fuels like natural gas and new technologies like electric and hybrid vehicles, hydrogen as fuel, the overwhelming contribution of petroleum products to transport sector is undeniable. The alternative fuel technologies have been relatively more expensive for a long time and that has been pivotal to the unprecedented growth of petroleum product demand for transport sector.

Transport sector has been the second highest emitter of carbon dioxide (CO_2), after electricity and heat production sector, contributing almost 23 percent of CO_2 emissions globally and is the fastest growing end-use sector (along with industry). With increasing urbanization in developing countries and expanding needs of the growing population, growth in transport demand is inevitable, and if unchecked, it will have considerable impact on greenhouse gas (GHG) emissions and ambient pollution.

Under the Paris Agreement various countries have committed 'net-zero' targets. To complement the net-zero goals set by different countries, considerable mitigation efforts are put to decarbonise transport sector through multitude of policies– promoting non-motorised transport, active promotion of electric vehicles (EVs), consideration of hydrogen as fuel, biofuel blending with petroleum products, increasing market share of rail, investments in mass-transit, etc.

In this regard, addressing the **energy trilemma** – providing **access to affordable energy** to the citizens; ensuring **energy security** through secured supplies; and providing energy systems that are **environmentally sustainable,** is of particular concern for developing countries due to their limited access to resources, existing inequality in social fabric, and their population pressure. **With the growth and development ambitions of developing countries, like India, it is of paramount importance to strike a balance between the three.** Historically, petroleum products and natural gas have played a pivotal role in meeting the transportation demand of the society. They have been instrumental in providing affordable access to transportation for the citizens. Under the Nationally Determined Contributions (NDC), various countries have adopted mitigation strategies to reduce their GHG emissions from transportation. These strategies include the adoption of alternative fuel technologies, such as electricity and hydrogen as fuels, in transportation that are yet to mature fully compared to the established conventional fuel-based transportation systems. The relatively high cost of these technologies and their future cost dynamics may potentially impact the affordability of transportation, particularly in developing countries.



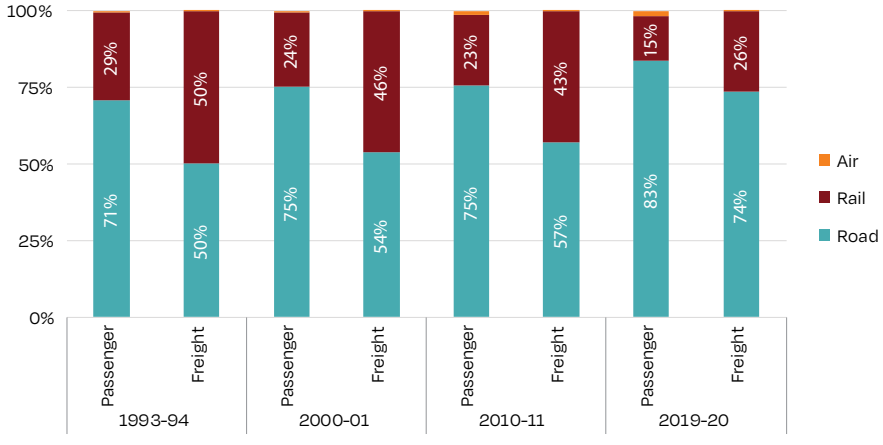
Need for the Study

Transport sector in India contributes 5 percent of gross value added (GVA), however, it has a much wider implication for country's development, connecting production centres with the consumption centres, and aiding labour mobility across the country. The share of transport in total CO_2 emission from energy use is 12 percent,[1] much higher than its sectoral share in GVA.

- Between 2000 and 2021, the **share of transport sector in total final consumption of energy has increased considerably from 11 to 16 percent.**
- **Road transport is the backbone of Indian transport system- contributing 83 percent of overall passenger and 74 percent of overall freight traffic in 2019–20.**
- Transport sector accounts for almost **80 percent of highspeed diesel (HSD) and 99 percent of petrol consumption in the country.**
- Per capita emission from transport sector was one of the lowest (among the major economies) at **0.282 tonnes of CO_2 equivalent in 2019–20.** However, it is growing at a rapid pace.

Consumption of HSD and petrol has increased significantly, 2.4 times for HSD and 4.7 times for petrol, between 2003-04 and 2023-24.

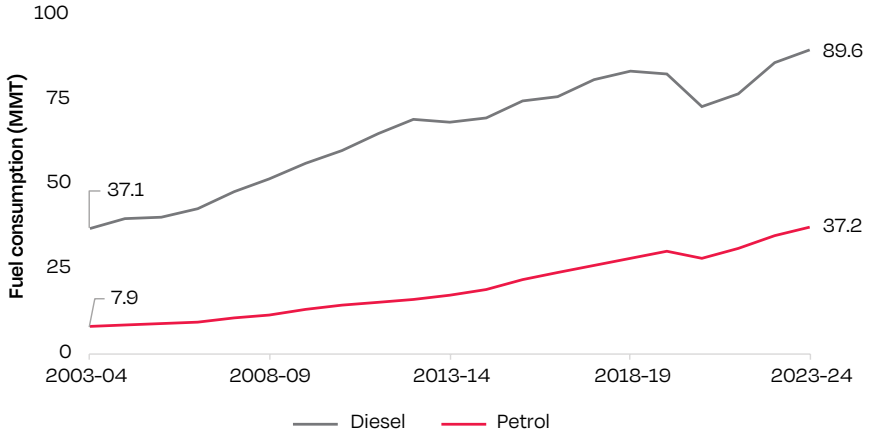
Figure 1: Shares of road, rail, and air in passenger and freight transport demand



Note: The numbers are rounded-off to nearest integers

Source: TERI

Figure 2: Total diesel and petrol consumption



Source: Petroleum Planning and Analysis Cell (PPAC)

[1] IEA. (2023). Transitioning India's road transport sector. France: International Energy Agency (IEA).

Though the emission intensity of India's GDP is continually declining over more than a decade, the emission intensity of transport sector in India has largely remained stagnant and at a higher level than the same for India's GDP. Thus, there is immense potential for the transport sector to contribute to the target set under India's Nationally Determined Contributions (NDC) – to reduce emission intensity of GDP by 45 percent over 2005 level by 2030. Moreover, given the expanding transport demand and criticality of some of the sectors, India's ambition to achieve net-zero emissions by 2070 and address the growing pollution in its cities are also linked to the transport sector of the country.

Objectives

This report focuses on assessing the impact of different low-carbon technology-driven pathways for the transport sector on its fuel demand and GHG emissions. The key objectives are:

- Develop a baseline scenario for the Indian transport sector encompassing different vehicle types across all modes of transport, for assessing fuel demand and GHG emissions
- Analyse different scenarios based on degrees of adoption of alternate fuel technologies, different biofuel blending prospects, and fuel efficiency improvement of vehicles, in terms of their impacts on fuel demand and GHG emission abatement potential
- Deliberate on the challenges associated with the low energy transition in transport sector and understand the policy implications of the alternative scenarios

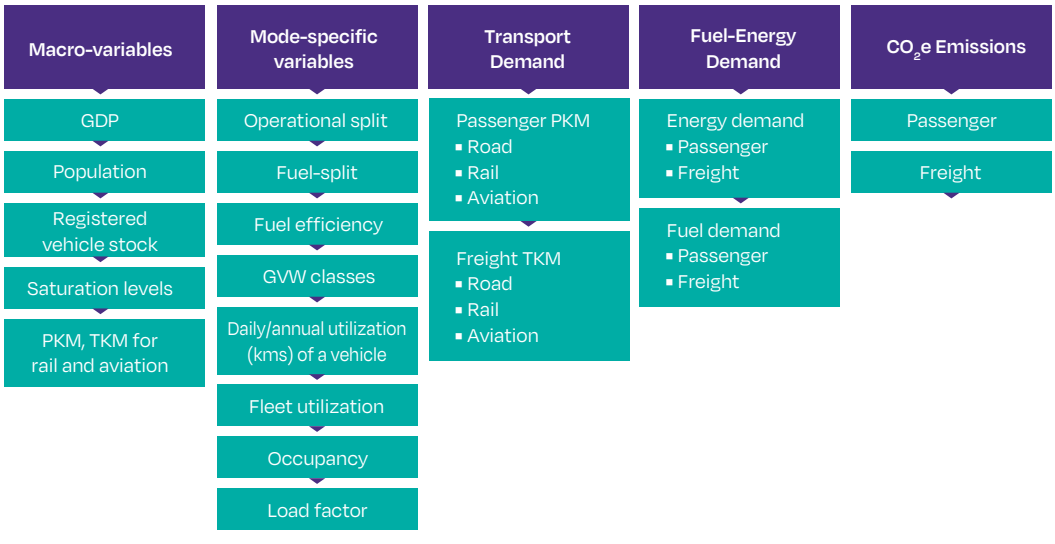
Methodology

This study uses the **TERI Transport Model** (TERI-TptM) which is a **bottom-up approach to estimate domestic transport demand** (passenger and freight). It first estimates the total transport demand, followed by estimations of the energy demand[2] and GHG emissions (measured by CO_2 equivalent emissions).

Model Description

The model is disaggregated by three modes of transport – road, railways, and domestic aviation.

Figure 3: Structure of the TERI Transport Model



Note: PKM- Passenger-km; TKM- Tonne-km; GVW- gross vehicle weight; coastal shipping has not been integrated into the model due to lack of data, however a short-term projection has been included separately.

Source: TERI

[2] Energy demand in this report represents the energy demand from various transportation fuels (petrol, diesel, liquid petroleum gas, aviation turbine fuel, natural gas, electricity, and hydrogen).

As a first step, transport demand is estimated for different modes of transport. Second, based on assumptions on fuel-split and operational characteristics of the road transport vehicles, corresponding energy and fuel demands are estimated. Once the fuel demand is estimated, as the final step, the GHG emissions are estimated based on fuel-specific emission factors.

Scenario Development

As part of the fuel demand and emission estimations, a baseline scenario and three decarbonisation scenarios (alternative scenarios) were developed. The scenarios are primarily technology-driven approaches to reduce GHG emissions from transport sector.

Government of India (GoI) has framed a multitude of policies on **biofuel blending** and identifying sectors for introducing alternative fuel technologies (involving battery electric vehicles and hydrogen fuel) as viable options for transport decarbonisation, along with greater push for natural gas as fuel. Railways with high degree of electrification of the route length and traction is also being considered as a viable mode for substituting road transport, thereby reducing GHG emission footprint. Further, improved technological efficiencies and revised **fuel economy standards** have clear impact on reduction of emission from internal combustion engine (ICE) vehicles and reduced energy requirements for alternative fuel vehicles. India is a party to the **EV30@30 campaign** that envisions a 30 percent EV share in the newly registered vehicles by 2030 and is moving fast with electrification of some of the modes of road transport, particularly three-wheelers.

EV adoption for medium and heavy goods vehicle (MHGV) segment is still very low in India, and apart from promoting electrification of this segment, use of **hydrogen and liquified natural gas** (LNG) are also being explored as alternative fuel options to replace diesel. In this regard the **National Green Hydrogen Mission**, launched in 2023, is worth mentioning. It aims to establish India as a global hub of production, usage, and export of green hydrogen and its derivatives. Presently, the production cost of green hydrogen is significantly higher than that for grey or blue hydrogen. A cost-effective yet cleaner hydrogen can provide India with GHG emission abatement potential at reasonable cost, before the country fully shifts to green hydrogen, when it becomes economically viable.

Government of India is actively promoting production, usage, and export of green hydrogen. However, the adoption path in transport sector is likely to start with low-cost gray hydrogen, to blue hydrogen, and then shift to the green hydrogen, when its cost of production reduces.

India is expected to expand its biofuel blending with petrol, diesel, compressed natural gas (CNG), and aviation turbine fuel (ATF). The updated **National Policy on Biofuels** has set a target of ethanol blending of 20 percent with petrol by 2025 and 5 percent blending of biodiesel with diesel by 2030. Additionally, the **CBG Blending Obligation** of the government targets a **5 percent blending of compressed biogas** (CBG) with CNG by 2028–29, and an indicative target set by the government on **use of sustainable aviation fuel (SAF) envisions a 2 percent SAF blending** by 2028 (initially for international flights).

To assess the effects of different policies on transport sector decarbonisation in India; **three alternative scenarios** were identified in this study–

- Policy-in-action (PIA)
- Ambitious
- Highly Ambitious

Further, under the Ambitious and Highly Ambitious scenarios, two pathways were considered, based on different levels of penetration of natural gas (CNG and LNG). These pathways consider the possibility of the existing price differential between petroleum products (diesel and petrol) and natural gas (for transportation) to wane in future, owing to growing import dependence for natural gas and increasing diversion of natural gas to the industrial sector (mostly ammonia production for fertilizers, and in oil refineries).

Table 1: Overview of scenarios

Scenarios	Fuel Economy Improvement	Fossil Fuels in Grid	EV Adoption	Hydrogen as Fuel (Bus and MHGV)	Blending Target
Baseline	Fixed rate	Fixed at present rate of 72%	Low	Nil	10% ethanol
PIA	Periodic improvement over the baseline	Gradual reduction of fossil fuel share to 0% by 2070-71	Meets 30% target by 2030, increased adoption thereafter	Low adoption	Meets biofuel blending targets by 2030-31 and continues thereafter
Ambitious	Same as in PIA	Same as in PIA	Meets 30% target by 2030, higher adoption thereafter than under PIA	Low adoption but higher than under PIA	Meets bio-fuel targets by 2030-31 and increased adoption wherever feasible
Highly Ambitious	Same as in PIA	Same as in PIA	Meets 30% target by 2030, significantly higher adoption thereafter than under PIA	Moderate adoption	Same as in Ambitious

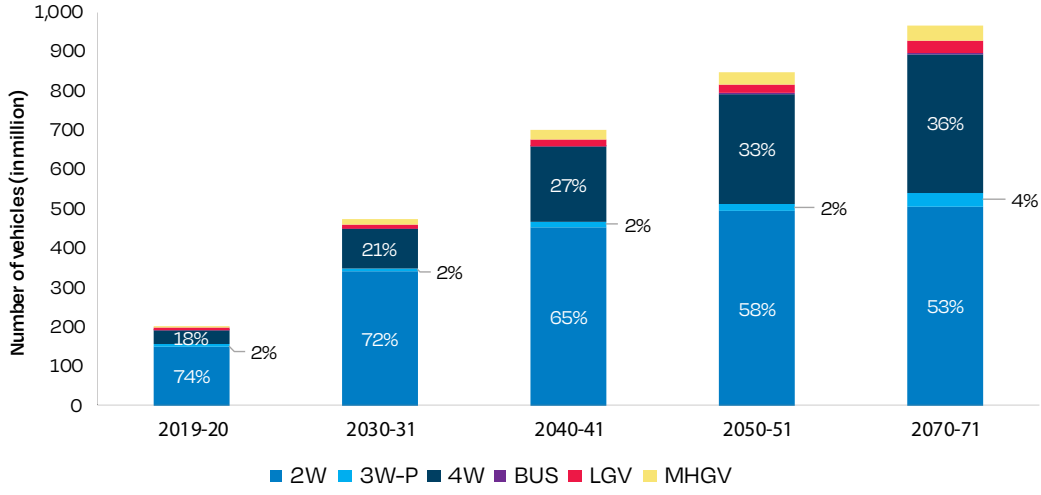
Note: Please refer to Table 6.2 in the main report for detailed assumptions.

Results

Transport demand in the model is derived demand and is kept constant across the four scenarios.

- **Passenger demand** is expected to increase from **7,303 billion passenger km** (BPKM) in 2019–20 to **26,983 in 2050–51,** and **34,284 BPKM by 2070–71,** a more than **four-fold increase** from 2019–20.
- **Freight transport** demand is expected to increase from 2,682 billion tonne km (BTKM) in 2019–20 to 20,644 in 2050–51, and 32,370 BTKM by 2070–71.
- Almost **five-fold increase in estimated number of on-road vehicles** between 2019–20 and 2070–71 (204 million in 2019–20, 474 million in 2030–31, 847 million in 2050–51, and 966 million in 2070-71), however, **the dominance of two-wheelers (2W) will weaken** due to larger adoption of four-wheelers (4W) in India.
- **A shift from modes with less GHG footprint per PKM (2W and Bus) to four-wheelers will be observed,** and by 2070–71 it is expected that the modal share of 4W will be more than the combined modal shares of Bus and 2W (31 percent). MHGV segment will increase its dominance in freight share, from 69 percent in 2019–20 to 89 percent in 2070–71. The share of railways in freight transport will decline from 26 percent to 8 percent during the same period.

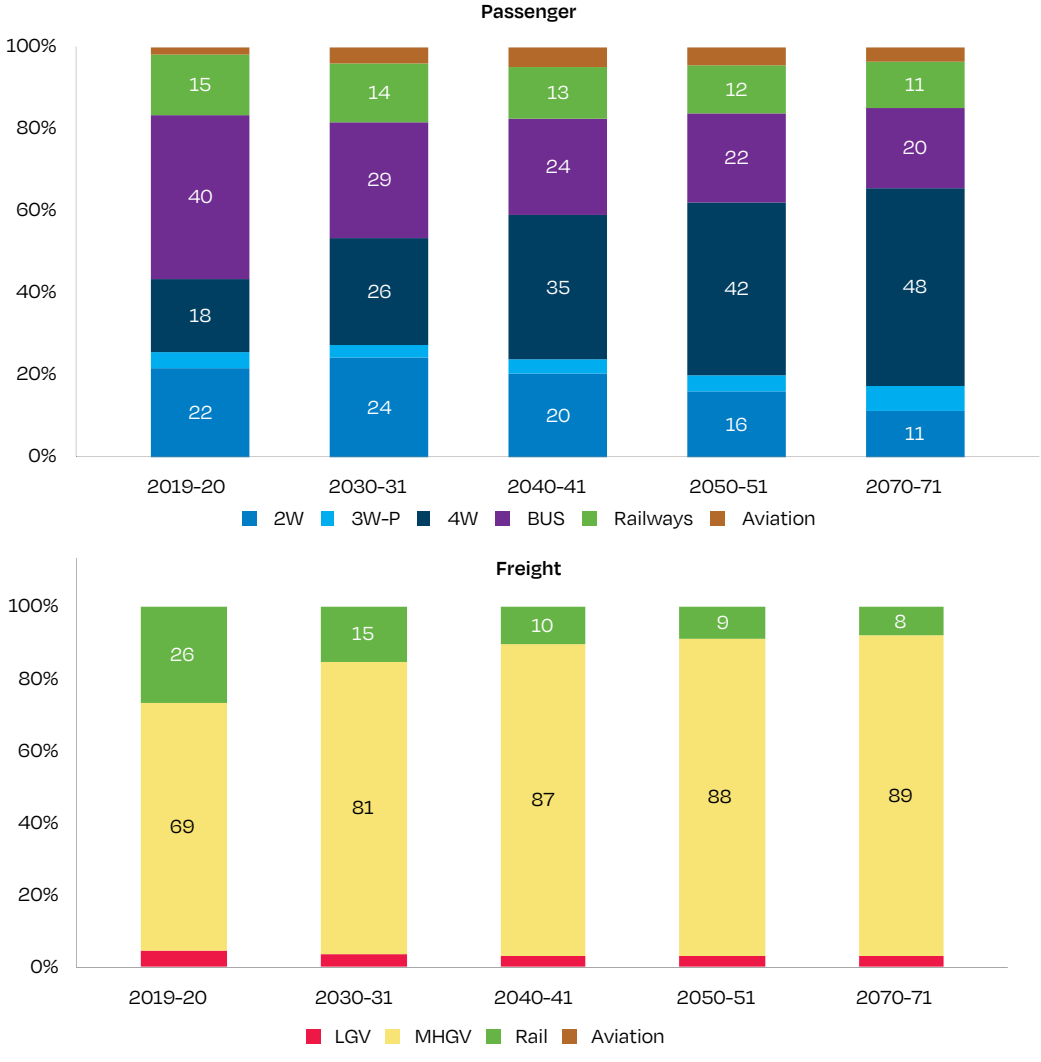
Figure 4: Estimated distribution of on-road vehicles



Note: 2W– two-wheelers; 3W-P– denotes three-wheeler passenger vehicles; 4W- denotes four wheeler cars & jeeps, and taxis; LGV– light goods vehicles (gross vehicle weight, GVW ≤ 7.5 tonnes); MHGV– medium and heavy goods vehicles (GVW>7.5 tonnes)

Source: TERI

Figure 5: Projected modal-split in transport



Note: Aviation has negligible contribution to freight transport and is expected to remain the same.

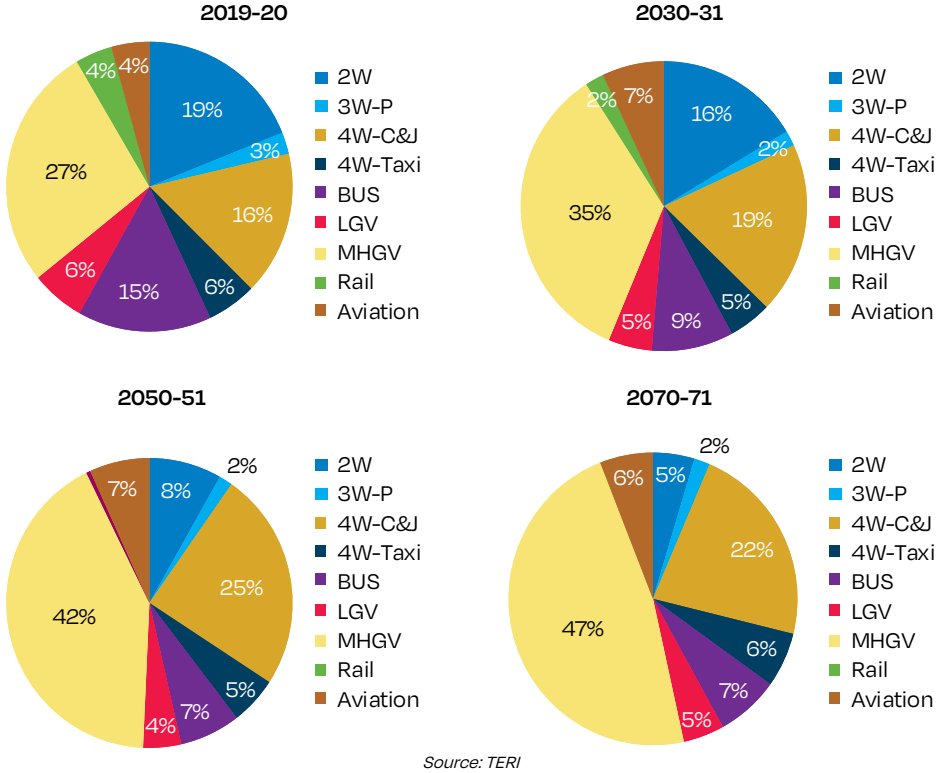
Source: TERI

Baseline Scenario

Under the baseline scenario–

- Energy demand from transport is expected to increase from 5.21 EJ[3] in 2019–20 to 12.27 EJ, 27.59 EJ, and 34.39 EJ in 2030–31, 2050–51, and 2070–71 respectively. **The dominance of passenger transport is expected to decline** from 66 percent of total energy demand in 2019–20 (3.43 EJ) to 50 percent (17.02 EJ) in 2070–71.
- **Energy demand** from fossil fuels will continue to increase; however, the growth will be at a declining rate, particularly for petrol and diesel.
- **Diesel demand** is expected to grow from 65 Mtoe in 2019–20 to 146 Mtoe in 2030–31, 337 Mtoe in 2050–51, 411 Mtoe in 2070–71. It is expected to stabilize starting 2060–61.
- **Petrol demand** is expected to expand from 34 Mtoe in 2019–20 to 75 Mtoe in 2030–31, and 133 Mtoe in 2050–51. However, petrol demand is expected to fall starting mid-2050 (a peak demand of 136 Mtoe)[4] and is expected to reach 127 Mtoe by 2070–71.
- **ATF demand** is expected to increase from 4.9 Mtoe in 2019–20 to 18.7 Mtoe in 2030–31, 40 Mtoe in 2050–51, and 42 Mtoe in 2070–71. ATF demand is expected to stabilize starting 2060–61 at 42 Mtoe.
- **Well-to-wheel** (WTW)[5] GHG emission from transport under the baseline scenario is poised to increase more than six times, from 391 million tonnes of CO_2e during 2019–20 to 914 million tonnes of CO_2e by 2030–31, 2,014 million tonnes of CO_2e by 2050–51, and 2,416 million tonnes of CO_2e by 2070–71.
- **Tank-to-wheel** (TTW) GHG emission is expected to grow from 312 million tonnes of CO_2e in 2019-20 to 735, 1,643, and 2,003 million tonnes of CO_2e respectively, in 2030–31, 2050–51, and 2070–71.
- **Road transport will continue to dominate the emission from transport with over 90 percent share.**

Figure 6: Transport sector WTW emission inventory



Source: TERI

[3] EJ = Exajoule, 1 EJ = 10^{18} Joule

[4] Mtoe- Million tonne of oil equivalent

[5] WTW emissions capture the overall GHG emission impact of the transport sector including the direct (operational/tank-to-wheel) and indirect (well-to-tank) impact of the vehicle use

Decarbonisation Scenarios

Under the three transport decarbonisation scenarios–

- **Energy demand from transport is expected to decrease under all the three scenarios compared to the baseline,** reaching peak at 28 EJ by 2067–68 under PIA, 25–26 EJ between 2065–67 under the Ambitious, and 22–23 EJ by 2052–54 under the Highly Ambitious scenarios respectively. Energy demand is expected to reach 12 EJ by 2030–31, and range between 22–24 EJ by 2050–51, and 20–26 EJ by 2070–71, under the alternative scenarios.
- In contrast to the projected even split of the energy demand between passenger and freight under the baseline scenario by 2070–71, **the share of passenger transport is expected to fall below 50 percent under the alternative scenarios by end of 2040s** with continued dominance of freight till 2070–71.
- **Petrol demand is expected to peak by 2044–45 at 94 Mtoe under PIA and at 89 Mtoe between 2040–42 under the Ambitious scenario, and 80–81 Mtoe between 2039–41 under the Highly Ambitious scenario.**
- **Diesel demand is expected to peak at 234 Mtoe by 2056–57 under PIA, at 186–207 by 2047–50 under the Ambitious scenario, and at 165–183 Mtoe under the Highly Ambitious scenario between 2043–45.**
- Consequently, demand for natural gas (CNG and LNG) is expected to grow considerably.

Table 2: Projected fuel demand (in Mtoe) in transport sector– Comparison of scenarios

Scenarios	Years	Fuel Demand (Mtoe)								
		Diesel	Petrol	LPG	ATF	CNG	LNG	Electricity	Hydrogen	TOTAL
2020-21		65	34	1	2	4	0	1	0	107
Baseline	2030-31	146	75	1	19	12	1	3	0	256
	2050-51	337	133	0	40	53	9	10	0	582
	2070-71	411	127	0	42	102	28	24	0	734
PIA	2030-31	136	69	0	19	17	1	6	0	249
	2050-51	228	89	0	38	99	23	35	6	518
	2070-71	181	33	0	34	163	65	75	57	608
Ambitious-Pathway 1	2030-31	131	69	0	19	21	4	6	0	250
	2050-51	183	68	0	38	116	48	45	13	511
	2070-71	89	0	0	34	168	130	98	75	593
Highly Ambitious-Pathway 1	2030-31	131	69	0	19	21	4	6	0	250
	2050-51	151	56	0	38	114	52	52	28	490
	2070-71	15	0	0	34	70	87	136	127	468
Ambitious-Pathway 2	2030-31	133	69	0	19	20	2	6	0	249
	2050-51	207	79	0	38	91	23	45	13	496
	2070-71	150	30	0	34	113	50	98	75	550
Highly Ambitious-Pathway 2	2030-31	132	69	0	19	21	2	6	0	249
	2050-51	173	67	0	38	90	29	52	28	476
	2070-71	35	19	0	34	42	57	136	127	450

Source: TERI

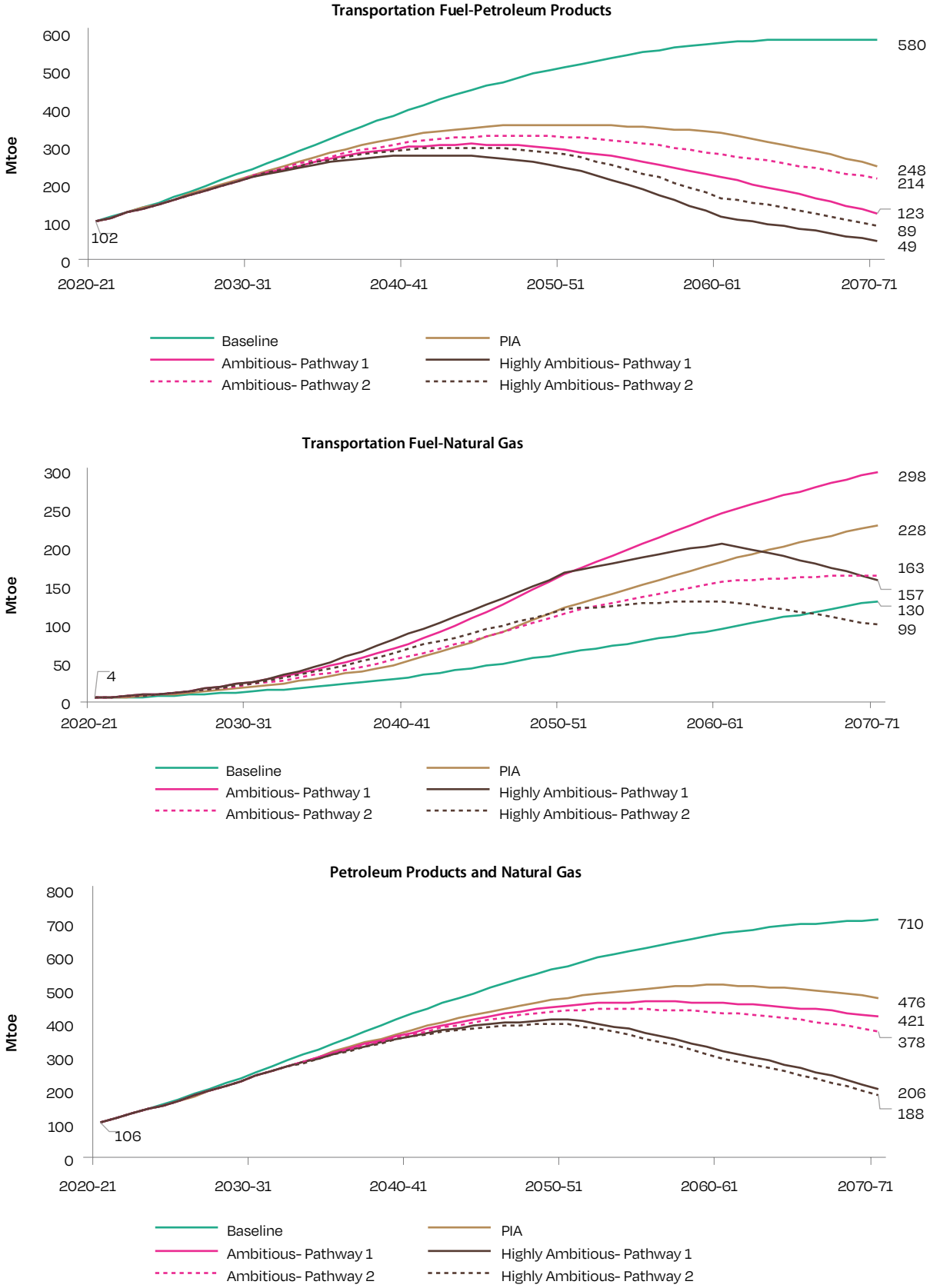
- Compared to the baseline, PIA pathway is expected to reduce petroleum product (petrol, diesel, LPG, ATF) demand by 7 percent in 2030–31, 30 percent in 2050–51, and 57 percent in 2070–71.
- **The impact of the Ambitious pathway** is much greater in terms of **reduction in demand for petroleum products,** by 8–9 percent in 2030–31, 36–43 percent in 2050–51, and 63–79 percent by 2070–71.
- Under the Highly Ambitious scenario the demand for petroleum product reduces by 9 percent in 2030–31, 45–52 percent in 2050–51, and 85–92 percent in 2070–71.
- **Overall fossil fuel demand for transportation** (petrol, diesel, LPG, ATF, CNG, LNG) **is expected to fall** by 4 percent, 17 percent, and 33 percent respectively, by 2030–31, 2050–51, and 2070–71 under the PIA scenario.
- Under the Ambitious scenario, fossil fuel demand is expected to fall by 4 percent, 21–23 percent, 41-47 percent respectively, in 2030–31, 2050–51, and 2070–71.
- **The Highly Ambitious scenario has the maximum impact of fossil fuel demand,** a reduction of 4 percent, 28–31 percent, and 71–74 percent respectively, in 2030–31, 2050–51, and 2070–71.

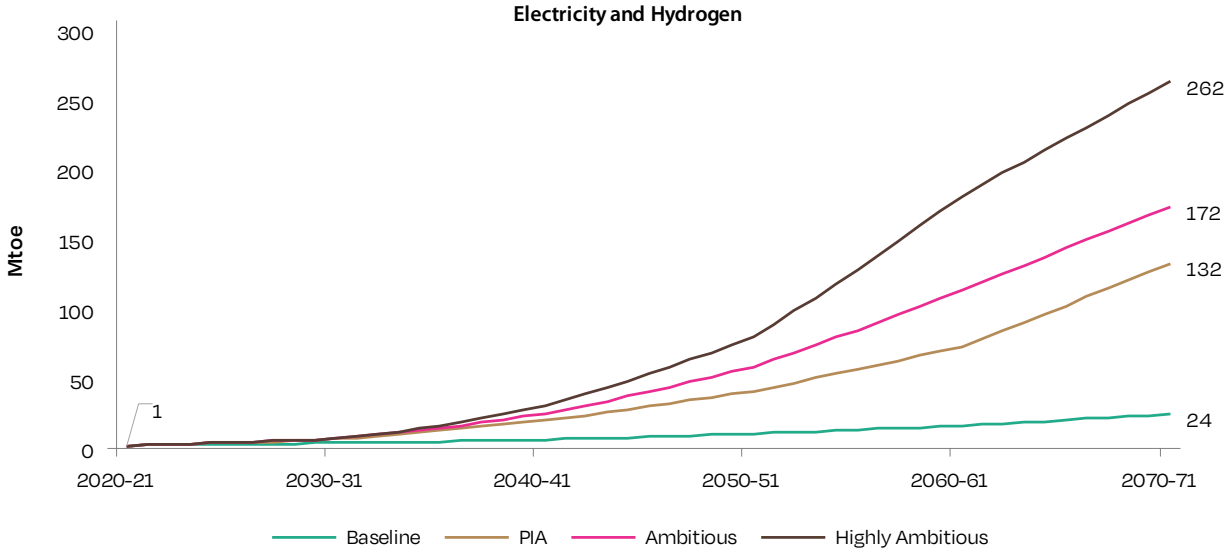
Restructuring of fossil fuel demand in transport

A visible shift from petroleum products to natural gas as transportation fuel.

- **By 2050–51, electricity and hydrogen demand** as transportation fuels is consequently expected to increase by **4, 6, and 8 times respectively,** under the PIA, Ambitious, and Highly Ambitious scenarios. In **2070–71,** it is expected to increase by **6, 7, and 11 times** respectively, under the PIA, Ambitious, and Highly Ambitious scenarios.

Figure 7: Fuel demand in Indian transport sector





Source: TERI

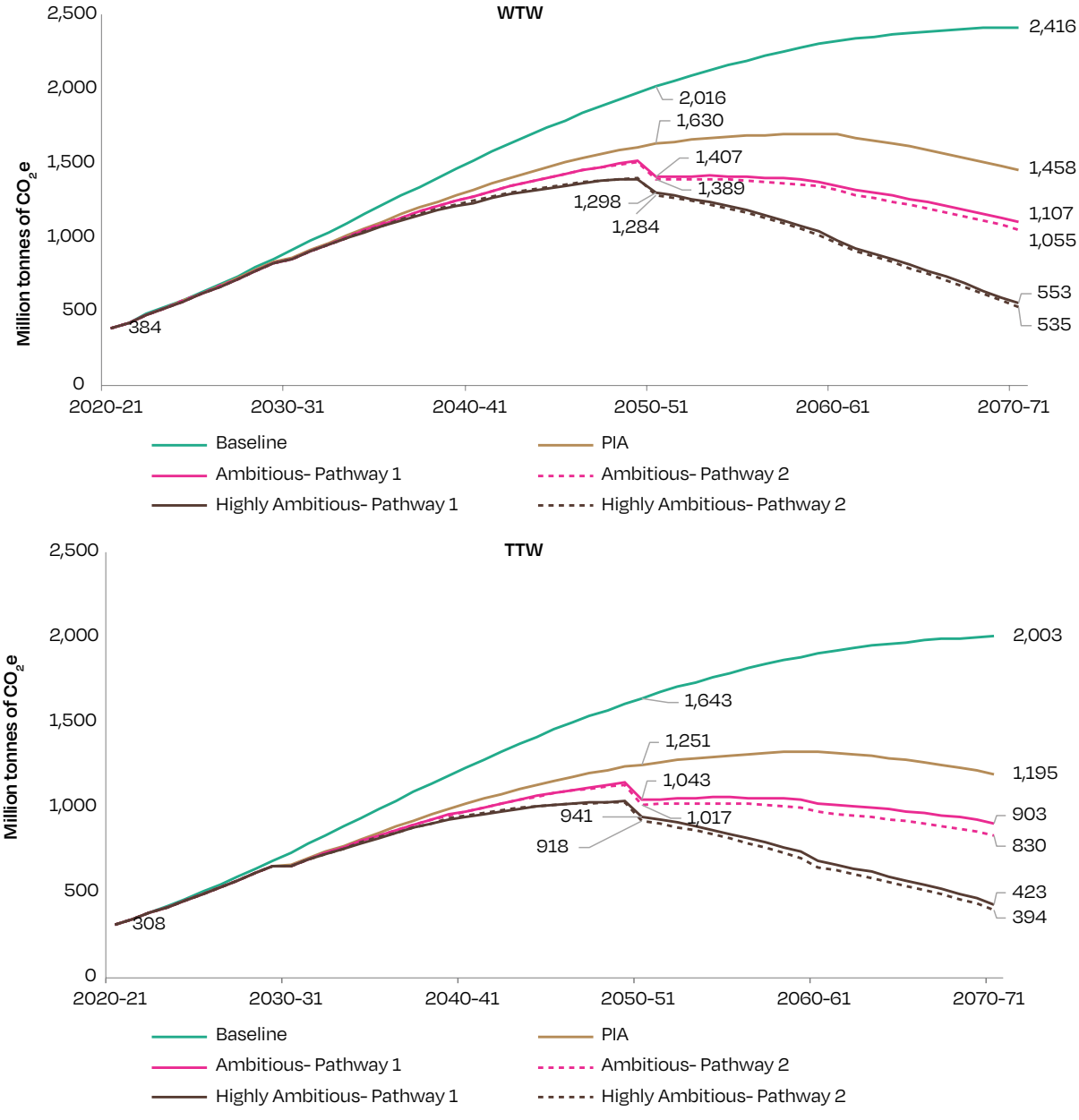
Table 3: Fuel demand

Scenario	Year	Fuel Demand						
		Petrol	Diesel	ATF	CNG	LNG	Hydrogen	Electricity
		Million Tonnes						Terawatt-hour
2020-21		29	63	2	3	0	0	11
Baseline	2030-31	65	140	18	10	0.4	0	37
	2050-51	114	323	38	43	7.4	0	115
	2070-71	109	394	39	82	22.8	0	275
PIA	2030-31	53	124	17	13	0.9	0	68
	2050-51	68	208	35	75	18.6	2.1	402
	2070-71	25	165	31	124	52.6	19.9	871
Ambitious-Pathway 1	2030-31	53	119	17	16	3.1	0.2	68
	2050-51	52	158	28	84	38.7	4.6	518
	2070-71	0	77	16	115	104.6	26.0	1,138
Highly Ambitious-Pathway 1	2030-31	53	119	17	16	3.1	0.2	67
	2050-51	42	131	28	83	41.6	9.7	602
	2070-71	0	13	16	48	70.0	44.1	1,578
Ambitious-Pathway 2	2030-31	53	121	17	15	1.6	0.2	68
	2050-51	60	179	28	66	18.7	4.6	518
	2070-71	23	129	16	77	40.6	26.0	1,138
Highly Ambitious-Pathway 2	2030-31	53	120	17	16	1.9	0.2	67
	2050-51	51	150	28	65	23.0	9.7	602
	2070-71	15	30	16	29	45.7	44.1	1,578

Source: TERI

- **Increased use of natural gas also provides expanding opportunity,** portraying a substitution from primarily a petroleum-based to a primarily gas-based transportation.

Figure 8: GHG emissions



Note: Only green hydrogen is considered in the model due to the unavailability of emission factors for other types of hydrogen. Please refer to Table 6.2 in the main report for detailed assumptions.

Source: TERI

- **All the three alternative scenarios** have WTW GHG **emission abatement potential of 6 percent by 2030–31,** as compared to baseline emissions.
- PIA scenario has WTW GHG emission abatement potential of 30–31 percent by 2050–51 and 40 percent by 2070–71, over baseline emissions.
- The Ambitious scenario has WTW GHG emission abatement potentials of 31 percent by 2050–51 and 54–56 percent by 2070–71, over baseline emissions.
- **The Highly Ambitious scenario** has WTW GHG **emission abatement potentials** of **36 percent by 2050–51** and **77–78 percent by 2070–71**, over baseline emission estimates.

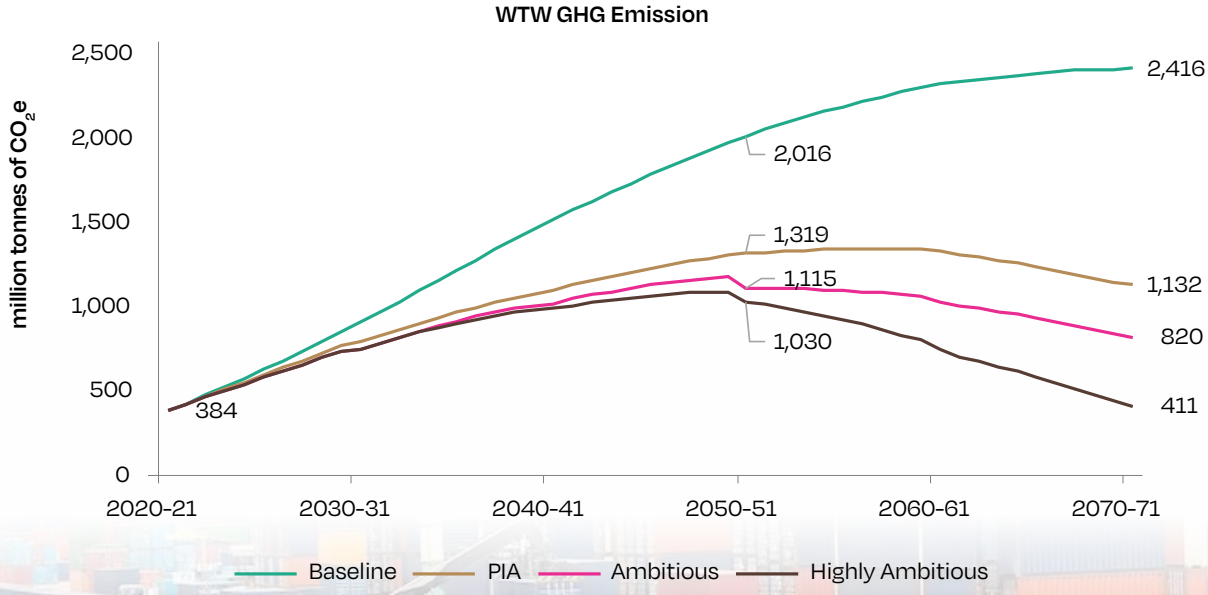
Case Study– Expanding Share of Railways

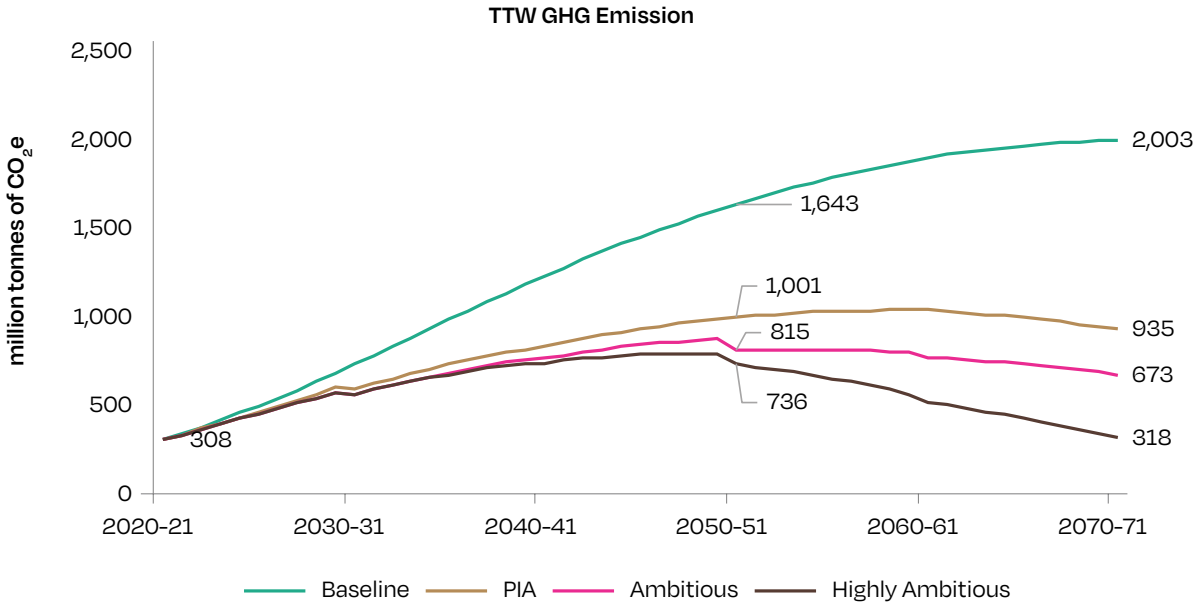
The share of railways in total freight transport has fallen below 30 percent by 2022. However, Indian Railways has planned to invest in various policies to attract freight loading on to its network, resulting in a **45 percent freight share in India. Any intermodal shift to the railways will be largely from the medium and heavy-duty trucks,** plying on longer routes. With an **exogenous assumption on a modest rise in the share of railways to 35 percent in 2030–31 and 45 percent by 2040–41** (under the PIA scenario), additional **emission reduction** of **8 percent by 2030–31, 19 percent in 2050–51,** and **22 percent in 2070–71** can be achieved compared to the baseline estimates of transport sector emissions. Further, if **aggressive attempts** are undertaken to expand **rail freight share to 45 percent in 2030–31** and **50 percent by 2040–41,** it could result in additional GHG **emission reduction** of **12 percent, 21 percent,** and **26 percent,** respectively, in **2030–31, 2050-51,** and **2070–71,** under the Ambitious and Highly Ambitious scenarios.

Dependence on fossil fuels for transportation purposes will continue but will largely be substituted by electricity and hydrogen.

The Highly Ambitious scenario holds great potential for decarbonisation of the sector.

Figure 9: GHG emission reduction impact of expanding share of railways in freight





Source: TERI

EV Transition– Battery Requirements

- Under the different scenarios, the total **EV projection** ranges between **220–858 million units,** and the corresponding **EV battery demand** ranges between **4.5–23.5 TWh by 2070–71** in the baseline and three alternative scenarios.
- With the increasing adoption of EVs across the passenger segments, **around 70 percent of the battery energy demand would be from passenger transport,** particularly from 4Ws.
- **MHGVs** will drive the demand for EV battery energy requirement in the freight segment, i.e., **10–29 percent** of the total road transport battery demand in the four scenarios.

- In lithium-ion nickel manganese cobalt (NMC) batteries, among the critical minerals, **nickel requirement is highest** with 72 percent of the total mineral requirement for the cathode, **followed by lithium,** i.e., 11 percent, and 9 percent cobalt and manganese.
- These high-nickel batteries would require 0.6 and 4.6 million tonnes in 2050–51, and 1.5 and 10.1 million tonnes in 2070–71 of lithium and nickel in PIA scenario, respectively.
- In the Ambitious scenario, there would be a requirement of 0.8 and 5.6 million tonnes in 2050–51, and 1.9 and 12.7 million tonnes in 2070–71 of lithium and nickel, respectively.
- In the highly ambitious scenario, 1.0 million tonnes of lithium and 7.0 million tonnes of nickel in 2050–51 and 2.6 million tonnes of lithium and 17.6 million tonnes in 2070–71 will be required to meet the EV demand.
- Corresponding to EVs on-road, **the lithium demand in PIA would be 201 percent higher, 287 percent higher in the Ambitious scenario, and in the Highly Ambitious scenario 425 percent higher,** compared to the baseline scenario. The supply chain of critical minerals can be made circular through cost-effective battery recycling technologies.

Table 4: Number of EV batteries in different scenarios (millions)

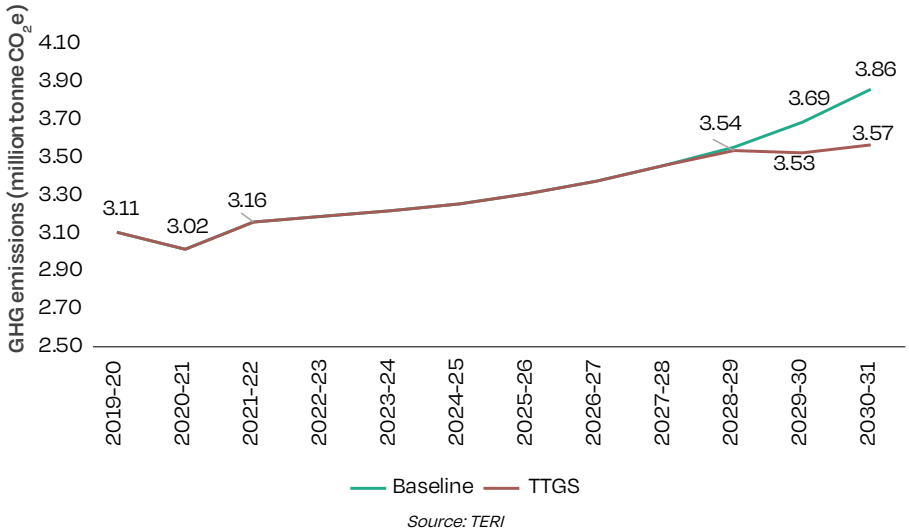
	2W	3W	4W	Bus	LGV	MHGV
Baseline						
2030–31	12.9	0.6	1.4	0.02	0.4	0.05
2050–51	68.8	6.0	27.4	0.08	3.2	0.7
2070–71	202.7	17.4	99.8	0.2	8.0	2.0
Policy-in-Action						
2030–31	77.2	2.7	6.6	0.2	0.6	0.3
2050–51	335.9	16.4	114.3	1.0	5.6	5.5
2070–71	570.6	52.8	257.2	1.8	12.7	13.2
Ambitious						
2030–31	77.2	2.7	6.6	0.2	0.6	0.3
2050–51	353.9	24.9	148.8	1.3	8.1	8.1
2070–71	760.3	52.8	307.3	2.0	19.4	19.8
Highly Ambitious						
2030–31	77.2	2.7	6.6	0.2	0.6	0.3
2050–51	450.4	27.5	164.9	1.5	10.8	9.7
2070–71	760.3	52.8	407.6	3.0	32.8	30.6

Source: TERI

Snapshot– Coastal Shipping

- With the increase in economic activity, **coastal cargo traffic is expected to grow to 1.7 times in 2030–31, as compared to 2021–22.**
- In Indian coastal shipping, **LNG** and derivatives of green hydrogen like **green ammonia/green methanol** are going to be key players in the decarbonisation of shipping. It is expected that the adoption of LNG and green ammonia (under the **Transition to Green Shipping, TTGS** scenario) could result in a GHG emission **reduction (well-to-wake) of 7.5 percent in 2030–31** compared to the baseline scenario. The emphasis forward is expected to be on derivatives of green hydrogen and LNG is likely to act as a transition fuel due to high GHG emissions in terms of complete life cycle.

Figure 10: GHG emissions by Indian flag vessels on coastal operation in 'transition to green shipping'



Source: TERI

Key Messages

- India's GDP and population are expected to continue with their growth trajectories, but growth of GDP is expected to dominate population growth. As a result, **transport demand will continue to grow. A four-times increase in passenger demand and 12-times increase in freight demand** between 2019–20 and 2070–71 are expected.
- **Number of passenger** vehicles is expected to grow from 193 million in 2019–20 to 897 million in 2070–71, **a growth of 4.6 times.** It will result in a **road PKM growth** from 6,098 BPKM to 29,251 BPKM, a **4.8 times increase.**
- **Number of goods vehicles** is expected to grow from 11 million to 69 million between 2019–20 and 2070–71, **a growth of 6.5 times.** However, the **road freight demand** is **expected to grow 15 times** from 1,974 BTKM in 2019–20 to 29,766 BTKM in 2070–71.
- With passenger transport demand being driven massively by private ownership of vehicles, especially cars and jeeps, **it becomes extremely important to act towards encouraging public transport.**
- **Fossil fuel will continue to play important role in India's transport sector,** though alternative fuel technologies will grow manyfold. Even under the Highly Ambitious scenario, the fossil fuel demand for transportation will start declining starting 2050–51 and reaching below the 2030–31 demand level by 2070–71.
- **Fossil fuel demand** is expected to range **between 188 and 206 Mtoe in 2070–71,** even under the aggressive transport decarbonization **(Highly Ambitious)** scenario.
- **Natural gas will dominate** the fossil fuel demand for transport sector, replacing the usage of petroleum products. Under the **Highly Ambitious** scenario, **natural gas demand** is expected to range **between 99 and 157 Mtoe in 2070–71.**
- Combined **demand for electricity and hydrogen** as transportation fuels is expected to increase to **262 Mtoe by 2070–71** under the **Highly Ambitious** scenario.
- **Over 60 percent of fuel demand** in 2070–71 is expected to be on account of **freight transport**.
- **Four-wheelers are expected to account for 52 percent of battery energy demand by 2070–71.**
- Government and private players must collaborate extensively to improve the frequency and scale of public transport services to reduce road congestion, overcrowding, and ensure social and environmental gains for all.
- With the increasing transport demand and corresponding rising

fuel demand, **the emphasis for transport decarbonisation lies in the increased adoption of cleaner fuels.** Solar rooftop charging can be explored for reducing dependence on grid and reduce GHG emission from use of electricity for EV charging.

- In case of transportation sector, **the adoption path of hydrogen as fuel is likely to start with use of grey hydrogen at the beginning,** to capitalise on its cheaper cost of production, followed by use of blue hydrogen in the medium-run, ultimately transitioning to green hydrogen as the prices become cheaper in the long-run.
- **Green hydrogen supply chain security** through international collaboration for fuel and critical minerals for fuel cells, needs to be strengthened where much of it is imported.
- **The fuel cell technology is at a very nascent stage.** For a transition like that of EVs, scaled-up demand incentives should be guaranteed for considerable periods, post pilots, across all stakeholders, to minimize investment risks.
- While the **electric vehicle technology** has started getting adopted in India, its **penetration is still very low in freight segment.** Further, mass adoption of electric vehicles requires massive expansion of charging infrastructure, technological advancements in battery technology, reduction in charging time without compromising battery health. **Hydrogen as transportation fuel is still at a very early stage of technological development.** But railways with over 90 percent of track electrification offers an existing solution to GHG emissions from transport. In addition to the emission abatement potential of railways in freight transport, inducing modal shift to railways for passenger traffic can further add to the **potential of railways in overall transport decarbonisation.**
- Infrastructure development needs to be put into action extensively by all stakeholders to meet the biofuel blending mandates. Long-term data inventories based on forecasts should be prepared for biofuel requirements to **manage food security, resource availability, and livelihoods.**
- With increasing transport demand, in the ambitious scenario, the GHG emissions would increase three times, from 391 million tonnes of CO_2e in 2019–20 to 1,130 million tonnes of CO_2e in 2070–71. The transport sector, which consists of hard-to-abate segments such as MHGV; aviation; and waterways; in isolation would not be able to achieve net-zero emission target by 2070–71. **Carbon credits, carbon offsetting measures, and combined efforts from different sectors of the economy should be adopted to achieve net-zero.**

Abbreviations

2W	Two-wheeler
3W-P	Three-wheeler passenger vehicles
4W	Four-wheeler
4W-C&J	Four-wheeler cars and jeeps
4W-T	Four-wheeler taxi
ATF	Aviation turbine fuel
BPKM	Billion passenger km
BTKM	Billion tonne km
CBG	Compressed biogas
CNG	Compressed natural gas
EJ	Exajoule
EV	Electric vehicle
GHG	Greenhouse gas
GoI	Government of India
GVA	Gross value added
GVW	Gross vehicle weight
HSD	Highspeed diesel
ICE	Internal combustion engine
LGV	Light goods vehicles
LNG	Liquified natural gas
LPG	Liquified petroleum gas
MHGV	Medium and heavy goods vehicles
MMT	Million metric tonne
Mtoe	Million tonne oil equivalent
NDC	Nationally determined contributions
NMC	Nickel manganese cobalt
PIA	Policy in action
PKM	Passenger km
PPAC	Petroleum Planning and Analysis Cell
SAF	Sustainable aviation fuel
TERI-TptM	TERI transport model
TKM	Tonne km
TTGS	Transition to Green Shipping
TTW	Tank-to-wheel
TWh	Terawatt hour
WTW	Well-to-wheel

The main report can be accessed using the given link/QR code:
https://teriin.org/project/roadmap-indias-energy-transition-transport-sector

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