International Transport Forum

Life-Cycle Assessment of Passenger Transport

An Indian Case Study

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Contents

Summary

Decarbonisation is a critical decision-making criterion for transport sector investments, along with others like accessibility and economic and strategic benefits. Objective, data-driven approaches help decision makers assess the decarbonisation potential of policies and of investing in alternative transport modes and the vehicle and fuel technologies associated with them.

This report presents a decision-making approach based on **life-cycle assessment** (LCA), which considers not only the carbon emissions from a vehicle's use, but also from its manufacturing, delivery and infrastructure needs. LCAs provide an effective means of understanding the impact of alternative policy choices on greenhouse gas (GHG) emissions.

The analysis in this report incorporates various **decarbonisation** scenarios for India's power grid. The grid energy mix for 2022 is considered as the base case. The Intended Policy Scenario (IPS) of grid decarbonisation (reflecting India's commitment to the 2015 Paris Agreement adopted at COP21) is used as the reference scenario.

Alternative scenarios of (a) maintaining a constant grid mix (even in the future) and (b) achieving India's "Net zero by 2070" target (announced during COP26) are also presented.

The study finds that to reach these objectives, Indian cities need to make public transport more attractive to users of private vehicle users and simultaneously transition to electric buses powered entirely by renewable energy to meet India's ambitious Low Emission Development Strategy, declared at COP27.

The largest achievable GHG emissions reduction in urban passenger transport amount over the lifetime of a bus amounts to ~1 300 tCO_2e. This would be achieved by **attracting users of cars and two-wheelers to buses**, even buses powered by internal combustion engine. The **transition to electric buses** can save around 460 tCO_2e of GHG emissions, based on the IPS scenario.

Powering all buses by renewable energy will cut a further 680 tCO_2e from urban passenger transport emissions, during the lifetime of a bus.

Recommendations

Initiate a shift to buses and prioritise their electrification

Promote electric two- and three-wheelers

Encourage a shift in the car fleet towards shared electric vehicles

Choose corridors with high passenger demand for new metro lines

Mainstream life-cycle assessment into public policy and investment decisions

Accelerate the transition to battery electric vehicles and complement it with the provision of cleaner energy

Recommendation 1

Initiate a modal shift from private vehicles to buses and prioritise their electrification

Emissions of battery-electric buses are at least 24% lower than electric two – and three-wheelers, 71% lower than private cars and 79% lower than shared cars.

Cities will benefit significantly from adopting a twin strategy of shifting users from private vehicles to public transport and at the same time electrifying buses.

Recommendation 2

Promote electric two- and three-wheelers

Light motor vehicles have a large share of the vehicle fleet in Indian cities. Accelerating their electrification avoids lock-in effects and can lead to high overall reductions of GHG emissions.

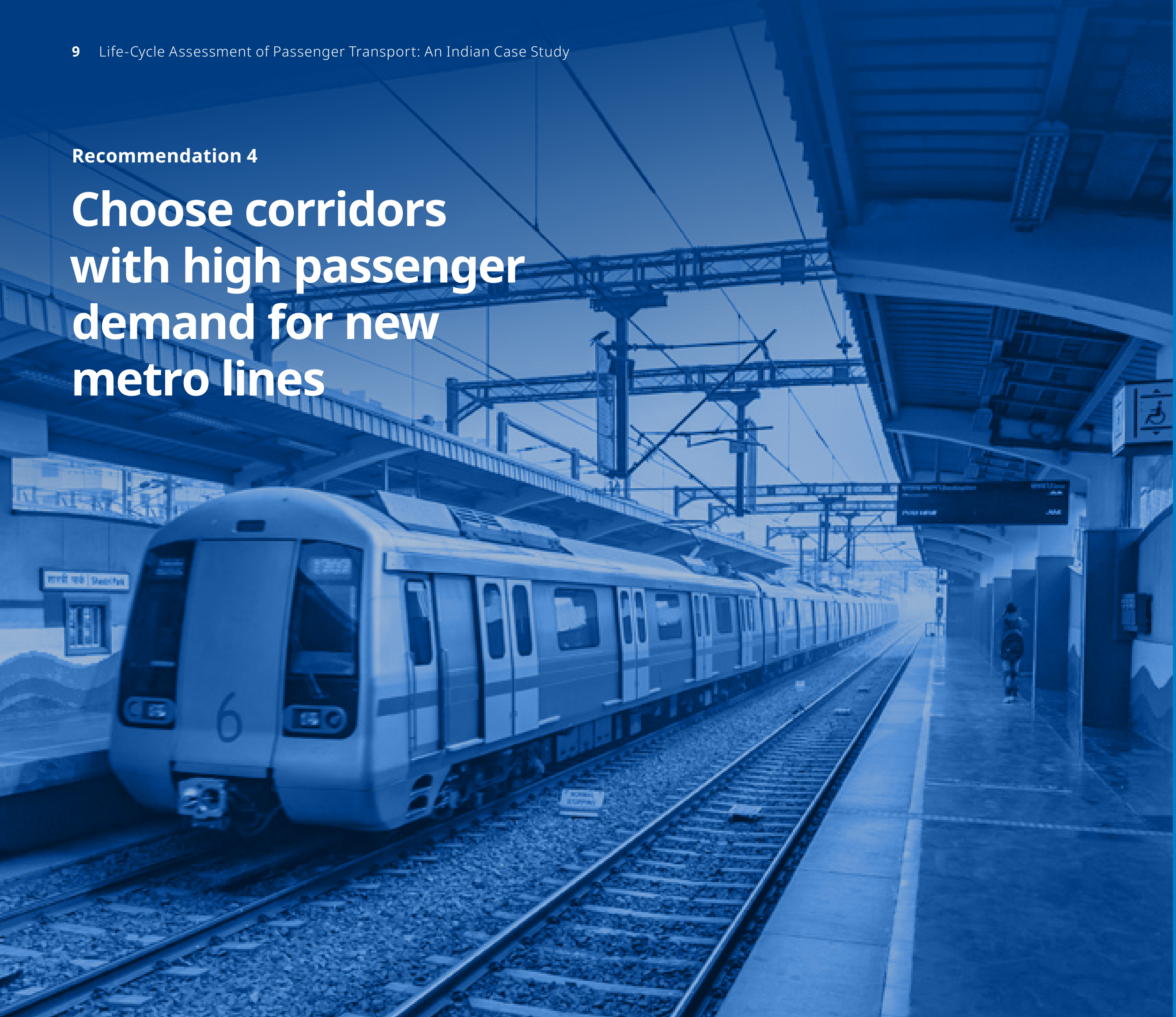
An electrified two- and three-wheeler fleet would emit only 28% to 57% of the CO_2 produced by fossil-fuel-powered mopeds and rickshaws.

Recommendation 3

Encourage a shift in the car fleet towards shared electric vehicles

Over their life cycle, shared electric cars emit 50% less GHG than comparable diesel-fuelled shared cars.

The emissions savings of private electric cars compared to private petrol-fuelled cars are significantly lower, at only about 27%. This is because the former clock far fewer kilometres than shared vehicles.



Recommendation 4

Choose corridors with high passenger demand for new metro lines

Metro rail systems have the lowest operating emissions but relatively high emissions embedded in their infrastructure and rolling stock.

Therefore, setting high targets for ridership and meeting them is crucial to realise GHG savings from the introduction of metro rail systems.

Recommendation 5

Mainstream life-cycle assessment into public policy and investment decisions

Manufacturing contributes up to 37% of life-cycle GHG emissions of battery electric vehicles due to the emissions intensity of battery manufacturing. The share of infrastructure GHG emissions can reach 25%.

Both must be taken into consideration when setting emission reduction targets, and the findings of life-cycle assessments must guide public policy and investment decisions.

Recommendation 6

Accelerate the transition to battery-electric vehicles and complement it with the provision of cleaner energy

Battery-electric vehicles have much lower GHG emissions than similar vehicles powered by internal combustion engines.

To maximise emissions reductions, it is vital that India achieves the goals of its announced clean energy policy.

List of abbreviations

2W	Two-wheeler
3W	Three-wheeler
CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalent
BEV	Battery electric vehicle
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
GHG	Greenhouse gas
ICE	Internal combustion engine
IPS	Intended Policy Scenario
kmpl	Kilometres per litre
kWh	Kilowatt-hour
LCA	Life-cycle assessment
OEM	Original equipment manufacturer
pkm	Passenger-kilometres
RE	Renewable energy
TCO	Total cost of ownership
vkm	Vehicle-kilometres

Scope of the study

The goal of this study is to create an understanding of the life-cycle greenhouse gas (GHG) emissions of passenger transport modes relevant to the Indian context and analyse, in depth, the GHG impact of different powertrains for buses in the urban and inter-urban context in India.

The study uses ITF's Transport Life-Cycle Assessment Tool for India and presents results for passenger transport modes, including **private and shared transport modes** (cars including taxis and ride-hailing services, such as Uber or Ola and two-wheelers) and **public transport modes** (three-wheelers, buses and metro-rail systems.

Both private and shared transport applications of cars and two-wheelers were analysed. Buses were analysed for varying operating conditions (urban and intercity), and bus types considered were 12m- vs 9m-long buses and air-conditioned (AC) vs non-AC buses.

The vehicle technologies considered for the study were internal combustion engines (ICE), battery electric vehicles (BEV), and fuel cell electric vehicles (FCEV).

The fuel types considered were diesel, petrol, compressed natural gas (CNG), blue hydrogen (CNG-based) and green hydrogen (100% renewable energy based).

Energy supply was analysed for three scenarios:

- **Intended Policy Scenario (IPS):** Transition of the electricity grid to clean energy based on previously announced policies (COP21, 2015)
- **Net Zero:** An accelerated energy transition to meet Net Zero targets, as proposed by the government of India (COP26, 2021)
- **100% Renewable Energy (RE) for buses:** For the case of buses, the additional scenario of the bus being powered entirely by RE was also analysed, given that authorities and operators are already establishing such arrangements as a part of their clean energy and cost-saving measures.

Two additional scenarios were also considered:

- A scenario for battery electric intercity buses powered by 100% renewable energy, comparing them with hydrogen-powered intercity buses.
- A constant emission energy scenario. Because India's on-going energy transition already involves a continual increase in the share of renewable energy, maintaining a current-energy-mix scenario is not realistic. However, such a scenario indicates the likely GHG emission impacts of alternative technologies in the immediate future. The summary results of this scenario are presented at the end of the report in Annex A.

The outputs generated for this study include the life-cycle assessment of passenger transport greenhouse gas emissions, measured as:

- Total GHG emissions of the vehicle over its lifetime
- Average GHG emissions per vehicle kilometre (vkm) travelled
- Average GHG emissions per passenger kilometre (pkm) travelled.

Greenhouse gas emissions of each phase within the overall life-cycle of the vehicle, as follows:

- Vehicle and battery manufacturing
- Transporting the vehicle to the point of sale
- Vehicle usage, including emissions from the production of the required fuels/energy
- Related infrastructure.

The report presents the LCA analysis in the following order:

- Outline of the key inputs, assumptions and outputs from the LCA analysis
- Summary of the key mode-specific assumptions used for the analysis
- Transport-mode-specific analysis for alternative energy-mix scenarios. This includes the lifetime GHG emissions of each mode, the GHG emissions per vkm travelled, and GHG emissions per pkm travelled.

Annex B presents the life-cycle PM2.5 emissions. The data sources for this report are summarised in Annex C.

This study establishes a reference LCA analysis for passenger transport modes in India based on the available secondary data for representative vehicle and fuel technologies.

It is acknowledged that the study does not consider vehicle types such as various types of passenger cars, CNG taxis, non-AC intercity buses and upcoming technologies such as sodium-ion batteries, recyclable batteries, etc.

Given the rapidly evolving technology scenario, several other technologies may need to be modelled in the future. The LCA tool on which this report is based has adequate flexibility to incorporate these options in the future and to update the analysis. Hence, readers are encouraged to benefit from the tool to derive context-specific results.

The case for life-cycle assessment

The growing demand for transport and vehicle use in India will increase energy use and CO_2 emissions by 2050. This has been observed in several modelling exercises.[1]

Most exercises conducted on the Indian transport sector focus on the direct CO_2 emissions produced at the vehicle tailpipe. However, it is also necessary to consider the upstream energy and emission impacts of fuel production and electricity generation, especially in the case of BEVs.

These upstream emissions represent a growing share of future transport emissions as alternative energy vectors – such as electricity, hydrogen, biofuels and electro-fuels – displace conventional petroleum-based fuels.

Furthermore, the impacts of energy and GHG emissions throughout the entire life-cycle and supply chain of transport services are significant, on top of the direct energy consumption and GHG emissions.

Emissions must be calculated through all stages of the life-cycle, including the extraction of raw materials; the processing and manufacturing of the vehicle; the transportation or distribution of the vehicle to the consumer; the use of the vehicle; production of the fuel/energy required to use the vehicle; the infrastructure created for the vehicle; and the disposal or recovery of the product after its useful life.

It is essential to assess the energy and GHG impacts of different transport services from a life-cycle perspective to take a holistic approach to transport decarbonisation.

India, which has committed to cutting its carbon emissions to net zero by 2070, unveiled a Long-term Low-Emission Development Strategy (LT-LEDS)[2] at COP27 in November 2022.

Decarbonising transportation is a key focus area in the strategy, which proposes increasing public-transport mode share and transitioning to cleaner vehicle technologies like electric and hydrogen-powered vehicles.

The relative benefits of alternative mobility and technology choices need to be analysed to prioritise national, regional and city-level actions to be pursued towards achieving these targets.

This requires quantitative analysis to address some of the questions faced by the sector:

- How green is the use of BEVs, given India's current and projected energy mix?
- What is the impact of the energy mix on GHG emissions?
- What is the GHG emissions share of various phases of the life-cycle of the vehicle-manufacturing, transportation, energy generation, usage, infrastructure and disposal?
- How do local operating conditions influence the GHG emissions of each mode of transport?

The life-cycle assessment presented in this study provides guidance on:

- The quantified GHG impact of investing in a transition to electric vehicles and hydrogen fuel-cell vehicles
- The relative GHG impact of different policy choices (e.g., electrify four-wheelers or increase bus usage?)
- LCA inputs for project-specific investment decisions.

The ITF life-cycle assessment tool for India

The ITF Transport Life Cycle Assessment (LCA) Tool for India estimates the energy consumption and GHG emissions associated with different modes of transport.

The tool aims to provide a holistic assessment of different transport options, accounting for energy use and GHG emissions that occur in different phases in the life of a vehicle, namely in:

- **Manufacturing**, including the assembly and disposal of materials associated with the vehicle and battery
- **Transport** to the place of commercialisation
- **Use**, including impacts associated with energy production for vehicle use
- **Operational services** needed by specific vehicles that possibly require other vehicles' involvement (this does not typically apply to private vehicles)
- **Infrastructure** construction and maintenance, according to relevant usage profiles (i.e. using an attributional approach, allocating energy and emissions occurring during construction and operation of infrastructures to the transport activity taking place on these same infrastructures).

The Tool and user guide are freely available for public use on the ITF website at: https://www.itf-oecd.org/itf-transport-life-cycle-assessment-india

The tool was developed as part of the ITF's Decarbonising Transport in Emerging Economies project.

Inputs and assumptions

The following inputs[3] were considered for each mode for various phases of its life-cycle:

- **Vehicle characteristics:** Vehicle lifespan, unladen weight, material mix, battery capacity, battery chemistry (lithium iron phosphate, nickel manganese cobalt), and number of batteries used during the life of the vehicle.
- **Distance and modes:** used to bring the vehicle from the manufacturing facility to the point of sale.
- **Vehicle use phase:** Operated km, fuel/energy efficiency, average occupancy and spare fleet needs for operational services.
- **Infrastructure:** roads, metro rail structures and tracks etc. and their life and material mix.
- **Energy-mix scenario timeline:** The energy-mix scenarios were tested assuming the 2022 grid (73% coal share) as the base case. In the Intended Policy Scenario, the coal share is 51% by 2030, and 21% by 2050 and in the Net Zero scenario, the coal share drops to 44% by 2030, and to 11% by 2050.

The diesel and CNG urban bus fuel-efficiency data are from Bengaluru and Delhi, respectively, while e-bus data are based on averages across five cities. Given the lack of access to secondary data, the intercity bus fuel efficiency is assumed to be the same as for urban buses. This is a conservative estimate since the improved driving conditions and speed on intercity services typically lead to better fuel efficiency compared to urban conditions.

Given that the vehicle's use phase constitutes the majority of GHG emissions in ICE vehicles and the fuel efficiency of ICE vehicles depends significantly on operating conditions, the diesel and CNG values presented here are not used to compare the performance of diesel vs CNG buses. Instead, they are used to derive the indicative GHG savings possible through transitioning to e-buses.

Additionally, the analysis conducted here is for the models with large batteries (324 kWh for 12m, 180 kWh for 9m), and the values would vary for models with smaller batteries.

Intercity buses of the 12m AC variety were analysed for the impact on GHG emissions of a transition to BEV as well as FCEV. Because urban buses are likely to continue on the BEV path given the total cost of ownership (TCO) savings already achieved[4], they are not considered for FCEV alternatives analysis. FCEV buses are analysed for two sources of hydrogen: blue hydrogen (CNG-based) and green hydrogen (100% renewable energy (RE) based).

All vehicles are assumed to be purchased in 2022. The grid emission factors consider the electricity grid's evolution within its lifetime.

The three tables on the following pages summarise the main assumptions, based on available secondary data supported by consultations with stakeholders in the government and the original equipment manufacturers (OEMs).

Modelling assumptions for cars, two-wheelers and three-wheelers

Mode	Application	Vehicle technology and fuel	Life of vehicle (years)	Distance driven (annual km)	Battery capacity (for EV, kWh)	Number of batteries replaced[5]	Fuel efficiency (for ICE, kmpl)	EV energy efficiency (kWh/km)
Car	Private	Petrol/EV	15	12 100	40.0	1	15.0	0.14
	Shared	Diesel/EV	10	48 000	50.0	1	14.0	0.14
Two-wheeler	Scooter-Private	Petrol/EV	10	6 500	3.7	1	50.0	0.03
	Scooter-Shared	Petrol/EV	6	18 000	3.7	1	50.0	0.03
	Motorcycle-Private	Petrol/EV	10	6 500	5.0	1	60.0	0.04
	Motorcycle-Shared	Petrol/EV	6	18 000	5.0	1	60.0	0.04
Three-wheeler	Shared	Diesel/EV	8	35 000	7.5	1	Diesel: 20.2 kmpl CNG: 29.5 kg/km	0.08

Sources for this data are available on page 44

Modelling assumptions for buses and metro

Mode	Type of bus/metro	Vehicle technology and fuel	Life of vehicle (years)	Distance driven (annual km)	Battery capacity (for EV, kWh)	Number of batteries replaced	Fuel efficiency (for ICE, kmpl or km/kg)	EV energy efficiency (kWh/km)
Urban Bus	Urban 12m AC	Diesel/EV	12	70 000	324	1	Diesel: 2.3 kmpl CNG: 2.4 km/kg	1.30
	Urban 12m Non-AC	Diesel/EV	12	70 000	324	1	Diesel: 4 kmpl CNG: 3 km/kg	1.10
	Urban 9m AC	Diesel/EV	12	60 000	180	1	Diesel: 3.0 kmpl CNG: 3.2 km/kg	1.10
	Urban 9m Non-AC	Diesel/EV	12	60 000	180	1	Diesel: 4.8 kmpl CNG: 4.0 km/kg	0.90
Intercity bus	12m AC	Diesel	12	122 500	365	2	2.3 kmpl	1.10
	12m AC	CNG	12	122 500	365	2	2.4 km/kg	1.10
	12m AC	Blue Hydrogen (CNG-based)	12	122 500	24	1	12 km/kg	1.10
	12m AC	Green Hydrogen (100% RE)	12	122 500	24	1	12 km/kg	1.10
Metro	Metro rail (6-car train)	EV	40	179 200	NA	NA	NA	17.72

Sources for this data are available on page 44

Note: Assumed values for buses: Life of vehicle, Annual-km driven, Fuel efficiency values of Diesel Urban 9m AC bus and Intercity CNG bus

Grid emission factors for all transport modes under each scenario

Mode	Application	Vehicle technology and fuel	Average occupancy (passengers/vehicle)	Life of infrastructure: road/metro rail system (years)	Grid emission factors in each scenario (gCO_2e/kWh)		
					BEV: Constant scenario	BEV: Intended Policy Scenario	BEV: Net Zero scenario
Car	Private	Petrol/EV	1.5	30	791	589	523
	Shared	Diesel/EV	1.0	30	791	640	576
Two-wheeler	Scooter-Private	Petrol/EV	1.0	30	791	640	576
	Scooter-Shared	Petrol/EV	1.0	30	791	684	626
	Motorcycle-Private	Petrol/EV	1.0	30	791	640	576
	Motorcycle-Shared	Petrol/EV	1.0	30	791	684	626
Three-wheeler	Commercial	Diesel/EV	2.0	30	791	662	600
Bus	Urban 12m AC	Diesel/EV	34.0	30	791	619	554
	Urban 12m Non-AC	Diesel/EV	34.0	30	791	619	554
	Urban 9m AC	Diesel/EV	25.0	30	791	619	554
	Urban 9m Non-AC	Diesel/EV	25.0	30	791	619	554
	Intercity 12m AC	Diesel/EV	25.0	30	791	619	554
Metro	Metro rail	EV	400.0	50	791	408	323

Findings

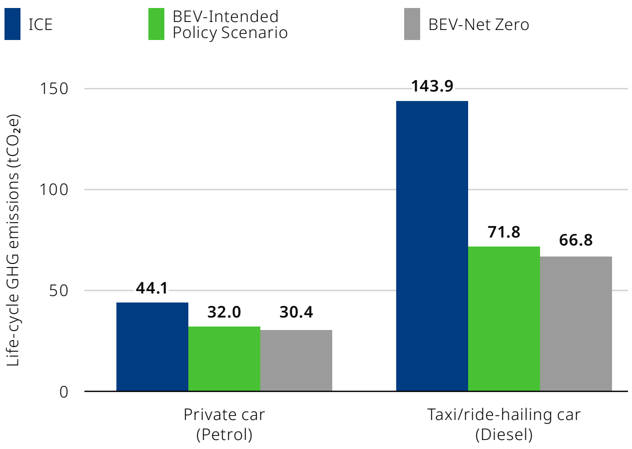
Private cars powered by electric batteries have lower life-cycle GHG emissions than fossil-fuelled cars in both tested scenarios. Sharing battery electric cars saves even more GHG per vehicle.

BEV private cars will have lower life-cycle GHG emissions compared to ICE (petrol) cars by ~12.1 tCO_2e in the IPS and by ~13.7 tCO_2e in the Net Zero scenario.

Shared cars used as taxis or ride-hailing services have significantly higher savings of ~51-68 tCO_2e life-cycle GHG emissions across all energy-mix scenarios because of higher lifetime utilisation. Life-cycle GHG emissions of shared cars are three times that of private cars for ICE variants but only ~2.2 times for BEVs.

Emissions per vkm for shared cars used for taxi or ride-hailing services are lower than for private cars, but the per-pkm emissions are worse as shared cars have lower effective occupancy (0.95) compared to private cars (1.5) due to deadheading between trips. The occupancy of shared-cars covers the effective-occupancy, i.e., passenger occupancy excluding the driver.

Life-cycle GHG emissions for cars



GHG emissions for private and shared cars under three scenarios

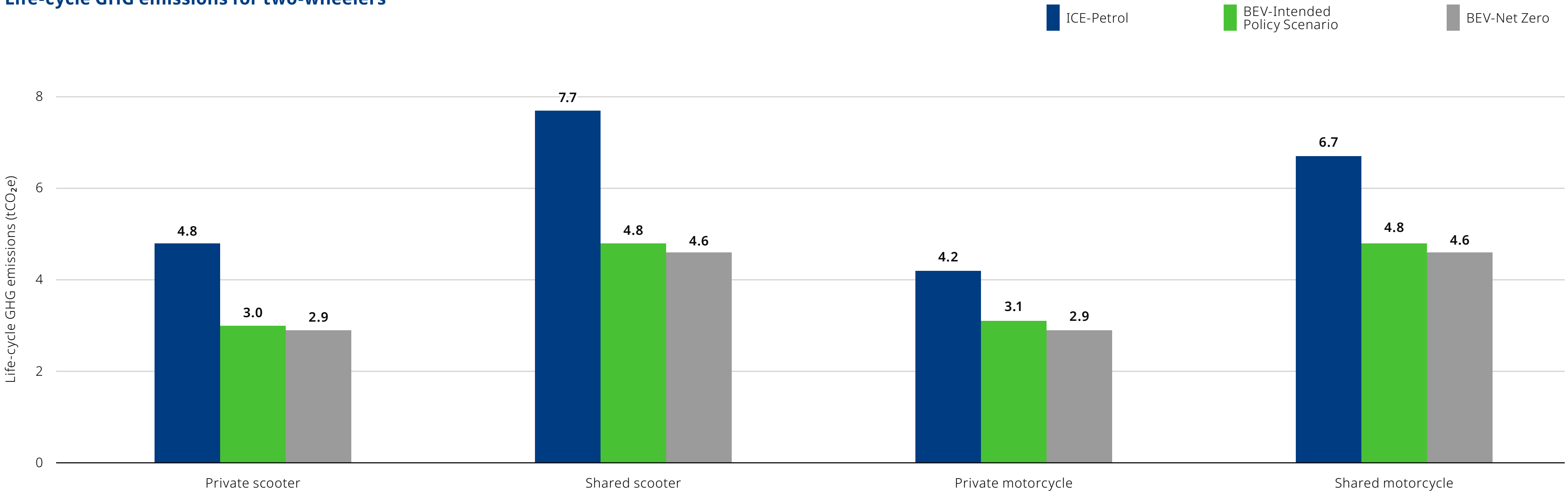
Scenario	GHG emissions per vkm (gCO_2e)		GHG emissions per pkm (gCO_2e)	
	Private	Shared	Private	Shared
ICE	243	241	162	298
BEV-Intended Policy Scenario	177	129	118	160
BEV-Net Zero	167	121	112	149

Private scooters save more GHG emissions than private motorcycles when both are battery electric.

Transitioning private scooters to BEVs can reduce their life-cycle GHG emissions by ~1.8-1.9 tCO_2e across all scenarios, while private motorcycles can save ~1.1-1.3 tCO_2e. BEV scooters are more efficient due to smaller batteries and fewer manufacturing-related emissions, whereas ICE motorcycles have better performance than scooters due to better energy efficiency.

Shared scooters and motorcycles can save ~1.9-3.1 tCO_2e of life-cycle GHG emissions depending on the use-case and energy scenarios. The additional benefits of the Net Zero scenario for 2Ws are limited due to their limited life or km-driven, which reduces benefit from grid improvements in later years.

Life-cycle GHG emissions for two-wheelers



The emissions per vkm and per pkm for two-wheelers are the same because a single rider is assumed. Emissions per vkm for ICE motorcycles are lower than for scooters due to higher energy efficiency.

Electric scooters and motorcycle models are still evolving and will likely have a longer life, larger battery and higher-powered variants in the future. Hence, these values are likely to evolve as more models become available in the market.

GHG emissions for private and shared two-wheelers under three scenarios

Scenario	GHG emissions per vkm (gCO_2e)				GHG emissions per pkm (gCO_2e)			
	Scooter (Private)	Scooter (Shared)	Motorcycle (Private)	Motorcycle (Shared)	Scooter (Private)	Scooter (Shared)	Motorcycle (Private)	Motorcycle (Shared)
ICE-Petrol	74	71	65	62	74	71	65	62
BEV-Intended Policy Scenario	46	45	47	45	46	45	47	45
BEV-Net Zero	44	43	45	43	44	43	45	43

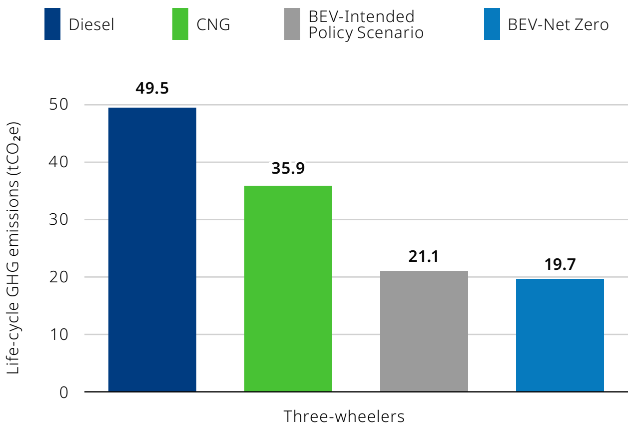
Electrifying three-wheelers will create substantial decarbonisation benefits.

Based on data from commercially-available models, electrifying diesel and CNG three-wheelers would deliver substantial benefits due to a combination of better energy efficiency and high daily mileage.

The impact is likely to increase further as newer BEV three-wheelers with better energy efficiency become available. Each diesel three-wheeler replaced by an electric model can save c. 28.4 tCO_2e of life-cycle GHG savings in the IPS scenario and c. 29.8 tCO_2e in the Net Zero scenario.

Replacing CNG 3Ws with electric would deliver ~14.9 and ~26.2 tCO_2e savings per vehicle over the life-cycle in these scenarios. Even the per-vkm and per-pkm emissions would reduce by 33–60% for both diesel and CNG 3Ws, depending on the energy mix scenario.

Life-cycle GHG emissions for three-wheelers



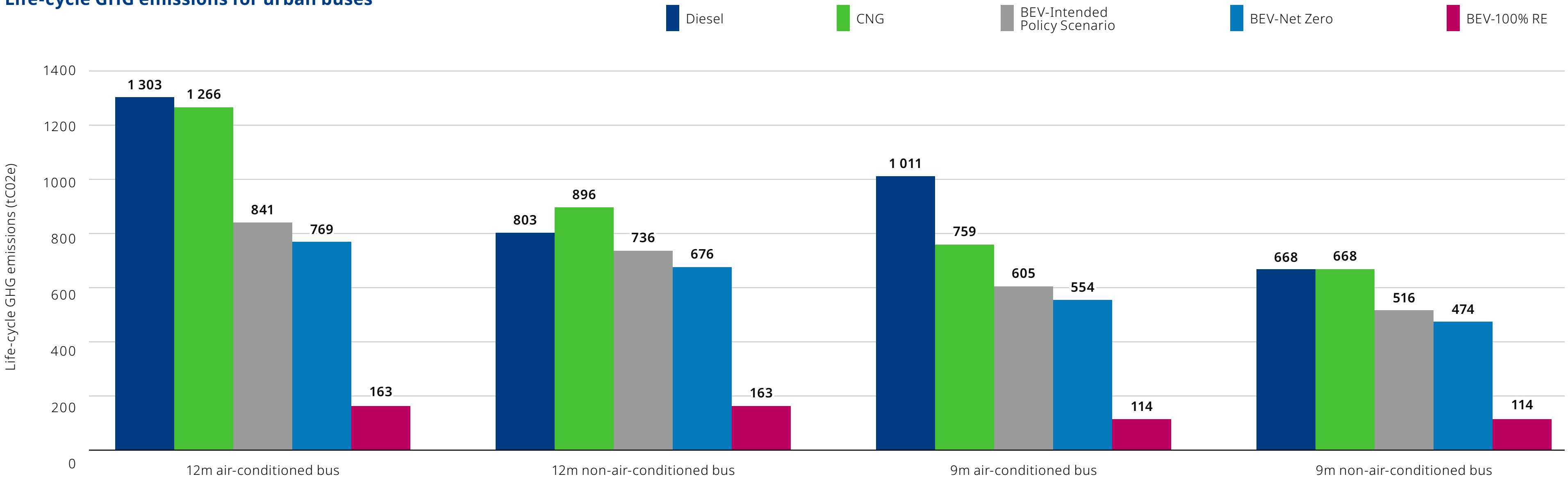
GHG emissions for three-wheelers under four scenarios

Scenario	GHG emissions per vkm (gCO_2e)	GHG emissions per pkm (gCO_2e)
ICE	177	104
CNG	128	75
BEV – Intended Policy Scenario	75	44
BEV – Net Zero	70	41

Electric urban buses have low emissions per passenger-kilometre, with air-conditioned buses saving more than those without AC.

Overall, air-conditioned buses deliver better GHG savings due to the higher energy-efficiency differential between BEV and ICE variants, while Non-AC buses (both 12m and 9m, diesel and CNG) operating in urban environments deliver less GHG savings. The operational energy savings are negated partly by the large vehicle and battery manufacturing emissions as the manufacturing share of emissions goes up to 17% for Non-AC buses, compared to 8–13% in the case of ICE vehicles. Some Indian cities are also establishing partnerships to use 100% RE to power e-buses, thereby reducing their operations costs and use-phase GHG emissions. Hence, the life-cycle GHG savings for RE-powered BEVs is analysed for the case of 12 AC buses to demonstrate the GHG implications.

Life-cycle GHG emissions for urban buses



Electric 12m AC buses in the IPS scenario have ~460 tCO_2e and ~425 tCO_2e lower life-cycle GHG emissions than diesel and CNG buses. In the Net Zero scenario, the life-cycle GHG emissions difference is ~535 tCO_2e and ~500 tCO_2e for diesel and CNG buses, respectively. The BEV scenario with 100% RE estimates ~1 100 tCO_2e of life-cycle reduction in GHG emissions compared to diesel and CNG variants.

In the case of 9m AC buses, electric buses under the IPS scenario for the grid have ~150 tCO_2e lower life-cycle GHG emissions compared to diesel and ~135 tCO_2e lower emissions than CNG buses. The savings compared to diesel and CNG buses in the Net Zero scenario are ~200 tCO_2e and ~190 tCO_2e, respectively.

Electric 12m Non-AC electric buses in the IPS scenario emit ~67 tCO_2e and ~160 tCO_2e lower GHG emissions over their life-cycles than diesel buses and CNG buses. In the Net Zero scenario, the life-cycle GHG emissions difference is ~127 tCO_2e and ~220 tCO_2e for diesel and CNG buses, respectively. Similar trends are observed even in the case of 9m buses. In the case of 9m Non-AC buses, e-buses have ~230–270 tCO_2e lower life-cycle GHG emissions compared to diesel buses and ~150-190 tCO_2e lower life-cycle GHG emissions compared to CNG buses in the two scenarios.

The GHG emission benefits of electrification of Non-AC buses are lower than AC buses, primarily because Non-AC ICE buses consume up to 40% less fuel compared to AC variants, while the difference is only about 20% in the case of e-buses. Therefore, the net GHG emissions impact of the Non-AC bus transition is lower than for AC buses.

Transitioning from Non-AC ICE buses to AC e-buses is likely to increase the life-cycle GHG emissions in the case of diesel buses (both 12m and 9m) but have net savings in the case of CNG buses (both 12m and 9m), based on the current performance in the reference-case cities considered in this study. As expectations for better-quality services grow, AC services will likely grow in significance.

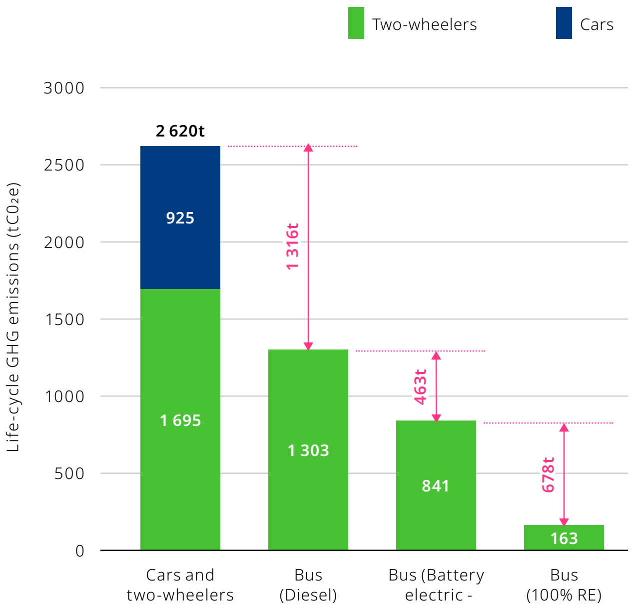
BEV bus emissions per vkm and per pkm are similar to the per-vehicle emission trends. The per-pkm emissions of buses are the best among all vehicle types due to their high occupancy levels.

GHG emissions for urban buses under five scenarios

Scenario	GHG Emissions per vkm (gCO_2e)				GHG Emissions per pkm (gCO_2e)			
	Urban 12m AC	Urban 12m Non-AC	Urban 9m AC	Urban 9m Non-AC	Urban 12m AC	Urban 12m Non-AC	Urban 9m AC	Urban 9m Non-AC
ICE-Diesel	1 548	954	1 051	784	46	28	42	31
ICE-CNG	1 504	1 064	1 028	926	44	31	41	37
BEV-IPS	998	875	838	715	29	26	34	29
BEV-Net Zero	914	803	767	656	27	24	31	26
BEV-100% RE	194	194	158	158	6	6	6	6

Cities shifting passenger transport to buses and electrifying them at the same time can save c. 2 500 tCO_2e of GHG over the lifetime of each bus.

Life-cycle GHG emissions for urban buses (tCO_2e)



The maximum reduction in GHG emissions in urban passenger transport would be delivered by **encouraging users of cars and two-wheelers to switch to buses** (i.e. passenger mode-shift), even ICE buses, this can deliver a GHG reduction of ~1 300 tCO_2e during the life of a bus.

The **transition from diesel to electric** in the IPS scenario will deliver ~460 tCO_2e GHG emission savings during the life of a bus, as mentioned earlier. **Powering these buses by 100% renewable energy (RE)** will deliver a further reduction of ~680 tCO_2e in GHG emissions.

Therefore, in order to meet the goals of India's ambitious Low Emission Development Strategy (LEDS) declared at COP27, Indian cities need to undertake active measures to encourage users of private vehicles to switch to public transport and transition to electric buses, preferably powered by 100% renewable energy.

The impact of introducing a high-quality electric bus service that reduces GHG emissions in this way is derived using the mode-wise LCA results presented in the report. The passenger-km served by a 12m AC urban bus over its 12-year life is used as a reference case for this analysis.

This demand is assumed to be attracted from private vehicles like cars and two-wheelers in a 20:80 ratio, based on their current mode split in cities like Chennai and Bengaluru.

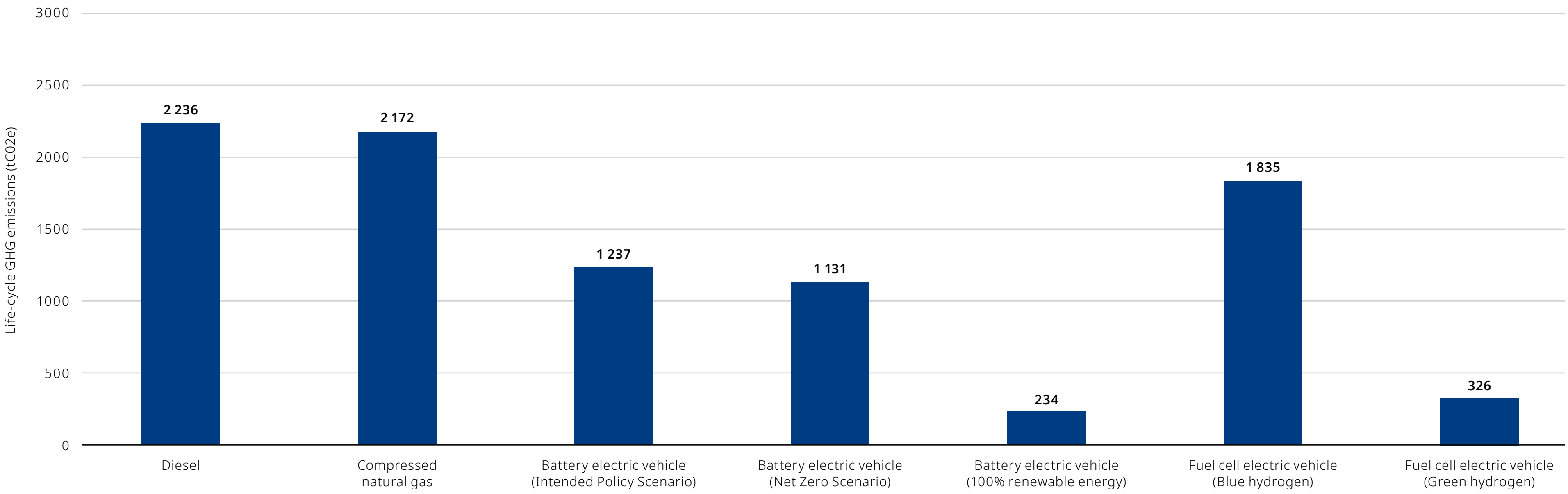
The demand associated with each vehicle is multiplied by the vehicles' respective emission factors to calculate the total GHG savings. Occupancy rates are 1.5 passengers for cars and one rider for two-wheelers, consistent with the values used for the rest of the analysis. The energy scenarios cover diesel, BEV-IPS and BEV powered by 100% renewable energy (as is being explored by cities like Mumbai).

For intercity travel, a transition to electric buses reduces GHG emissions considerably more than fuel cell electric buses using blue hydrogen.

Intercity e-buses emit ~1 000 tCO_2e (~45%) lower life-cycle GHG emissions compared to diesel buses in the IPS scenario and ~1 100 tCO_2 (~50%) in the Net Zero scenario. The GHG emissions savings from e-buses compared to CNG buses are ~935 tCO_2e and ~1 040 tCO_2e in the IPS and Net Zero scenarios, respectively.

Blue-hydrogen-based FCEVs have lower emissions than ICE buses but only save ~388 tCO_2e and ~324 tCO_2e of life-cycle GHG emissions, compared to diesel and CNG buses, respectively. Green-hydrogen-based FCEVs offer substantially higher savings of ~1 900 tCO_2e and ~1 835 tCO_2e of life-cycle GHG emissions, respectively, than do diesel and CNG buses.

Life-cycle GHG emissions of intercity buses with different propulsion systems



Battery electric buses powered by 100% renewable energy emit c. 28% less life-cycle GHG than fuel cell electric buses powered by green hydrogen.

Across the estimates for life-cycle emissions (in vehicle-km and passenger-km), it is apparent that Indian bus agencies would achieve higher GHG savings by transitioning to e-buses than to blue-hydrogen-based FCEVs. While green hydrogen is gaining popularity, battery electric buses with 100% renewable energy would lower life-cycle GHG emissions more than green hydrogen-based FCEVs.

Hydrogen-powered FCEVs have lower life-cycle GHG emissions compared to BEVs powered by the grid only when they are fuelled by green hydrogen. Blue hydrogen buses have higher GHG emissions compared to BEV buses. BEV buses powered by 100% renewable energy have lower life-cycle GHG emissions compared to green-hydrogen buses.

GHG emissions for intercity buses per vkm and per pkm

	GHG emissions per vkm (gCO_2e)	GHG emissions per pkm (gCO_2e)
Diesel	61	1 519
Compressed Natural Gas	59	1 475
BEV-Intended Policy Scenario	34	840
BEV-Net Zero Scenario	31	768
BEV-100% Renewable energy	6	159
FCEV-Blue hydrogen	50	1 246
FCEV-Green hydrogen	9	221

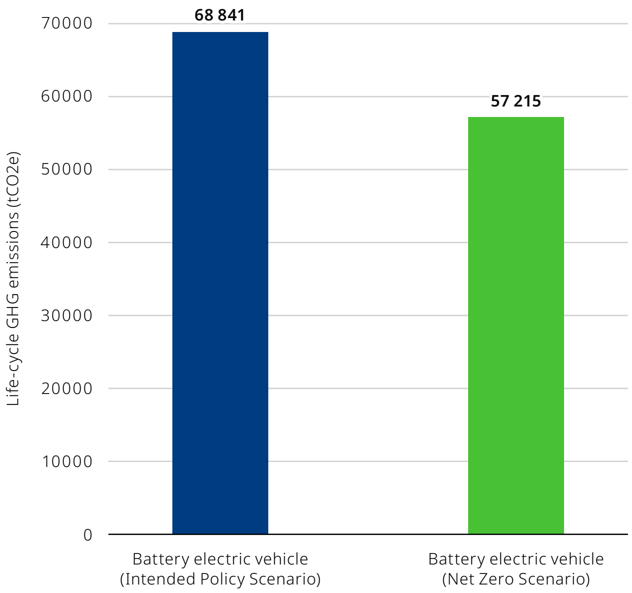
Metro rail systems have significant fixed infrastructure emissions but emit little per passenger-kilometre due to the large number of users.

Metro trains have a lifespan of around 40 years and operate c. 180 000 km per train per year on dedicated infrastructure. As a result, they accumulate high life-cycle emissions over the span of several decades. Metro rail achieves low life-cycle emissions when serving a high ridership.

The emissions per vkm are derived based on vehicle utilisation, as mentioned above. The emissions per pkm are derived assuming average demand of 6 000 peak hour peak direction traffic (phpdt) over the life of the metro, based on the performance of current Indian metro systems.

Metro rail systems with low ridership can have high emissions per pkm due to the embodied emissions caused by the infrastructure and the vehicle itself.

Life-cycle GHG emissions for a six-car metro train



Metro rail per vkm and per pkm under two scenarios

Metro rail	GHG emissions per vkm (gCO_2e)	GHG emissions per pkm (gCO_2e)
BEV – IPS	9 604	24
BEV – Net Zero	7 982	20

Summary of results for different modes: GHG emissions per vehicle in the IPS scenario, per vkm and per pkm

Mode	Application	Vehicle technology	Life-cycle GHG emissions (tCO_2e)			Life-cycle GHG emissions per vehicle-km (gCO_2e)			Life-cycle GHG emissions per passenger-km (gCO_2e)		
			Petrol/ Diesel	CNG	BEV-IPS	Petrol/ Diesel	CNG	BEV-IPS	Petrol/ Diesel	CNG	BEV-IPS
Car	Private	Petrol/EV	44.0	NA	32.0	243	NA	177	162	NA	118
	Ride-hailing	Diesel/EV	144.0	NA	72.0	257	NA	129	318	NA	160
2W	Scooter (Private)	Petrol/EV	4.8	NA	3.0	74	NA	46	74	NA	46
	Scooter (Shared)	Petrol/EV	7.7	NA	4.8	71	NA	45	71	NA	45
	Motorcycle (Private)	Petrol/EV	4.2	NA	3.1	65	NA	47	65	NA	47
	Motorcycle (Shared)	Petrol/EV	6.7	NA	4.8	62	NA	45	62	NA	45
3W	Commercial	Diesel/CNG/EV	49.0	36	21.0	177	128	75	104	75	44
Urban bus	12m AC	Diesel/CNG/EV	1 303.0	1 266	841.0	1 548	1 504	998	46	44	29
	12m Non-AC	Diesel/CNG/EV	803.0	896	736.0	954	1 233	875	28	31	26
	9m AC	Diesel/CNG/EV	759.0	742	605.0	1 051	1 129	838	42	41	34
	9m Non-AC	Diesel/CNG/EV	566.0	668	516.0	784	926	715	31	37	29
Inter-city bus	12m AC	Diesel/CNG/EV	2 236.0	2 172	1 237.0	1 519	1 475	840	61	59	34
Metro	Metro rail	EV	NA	NA	117 571.0	NA	NA	9 604	NA	NA	24

GHG emissions across vehicle types per life-cycle phase

Vehicle operations generate the highest share of life-cycle GHG emissions across modes and vehicle technology. Vehicle usage accounts for operations (tank-to-wheel emissions), fuel production (well-to-tank emissions), spare fleet, and shared/public transport vehicle deadheading.

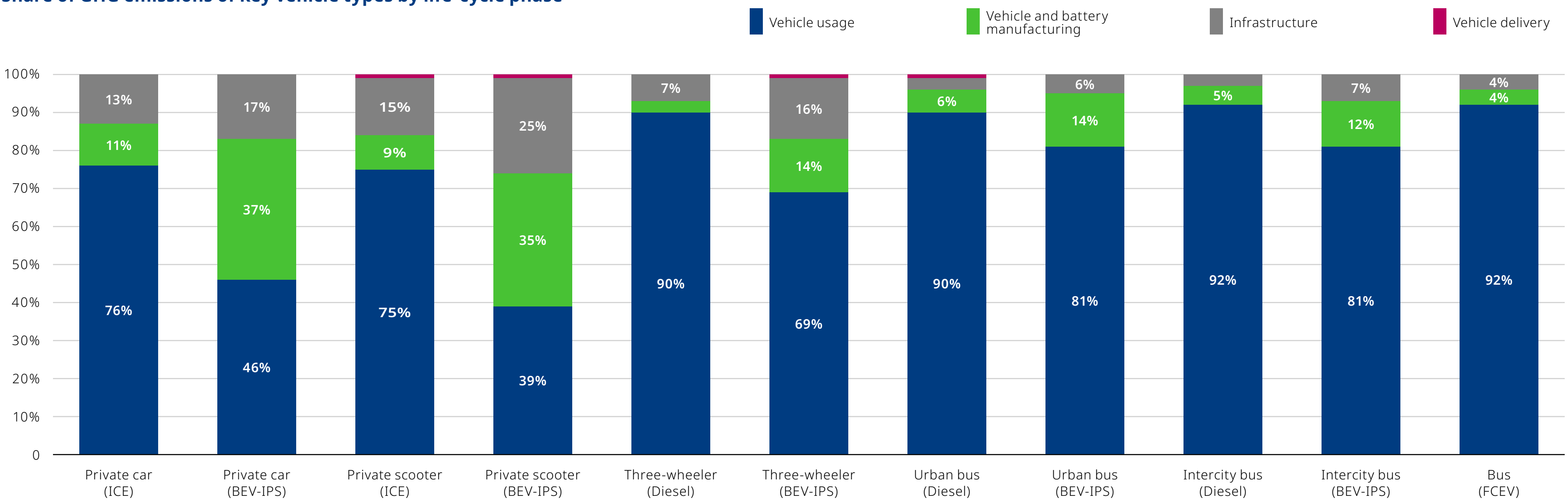
Private ICE cars and 2W emit the most due to the usage phase, whereas vehicle and battery manufacturing causes the most significant chunk of emissions for BEVs. 75-90% of ICE vehicle emissions are due to usage, 4-11% are due to manufacturing, and 5-16% are due to road/rail infrastructure creation. Regarding BEVs, the vehicle and battery manufacturing shares are significantly higher at 35-37% for private 2W and cars and 19-22% for shared 2Ws and shared cars. Shared vehicles have a higher share of usage-phase emissions due to higher operated-km even though the vehicle's life is shorter.

The usage phase of ICE 3W contributes to 90% of their life-cycle emissions, while for BEVs, manufacturing (14%) and infrastructure (16%) have a much higher share. In the case of buses, 78-92% of GHG emissions occur during the usage phase for both ICE and e-buses.

However, the share of the usage phase drops to 0% for 100% RE-based e-buses and 50% for green-hydrogen-based buses.

Metro rail systems have high infrastructure-phase emissions per vkm (2 091 g/vkm), but at a usage level of 6 000 phpdt mentioned earlier, their emissions per passenger-km (5 g/pkm) are lower than 3Ws (7 g/pkm), although they are higher than urban buses (2gm/pkm). As these metro rail systems get used more (i.e. 15 000 phpdt or more), they generate lower GHG emissions per pkm than buses. These numbers indicate the energy embodied in developing the fixed infrastructure needed for metro rail systems. Their role in decarbonising mobility is linked to their ability to attract high ridership. It is to be noted that the specific system choice between various modes depends on various other factors, such as the city's economic and spatial development, mobility characteristics and other strategic priorities. Hence, a context-specific review of these life-cycle emissions needs to be carried out to inform decision-making.

Share of GHG emissions of key vehicle types by life-cycle phase



Recommendations: Details

1. **Initiate a shift to buses and prioritise their electrification.** Battery electric buses have at least ~24% lower emissions per passenger-km compared to electric two – and three-wheelers, 71% lower than private cars, and 79% lower than shared cars. Cities have much to gain by adopting the twin strategies of electrifying buses and creating high-quality bus services, leading to users shifting from private vehicles to buses. Urban ICE (diesel) buses emit ~65-76% lower emissions per passenger-km (depending on the size and type) over their lifetimes than BEV private cars. Intercity buses offer the maximum total tons of per-vehicle GHG savings (~1 000 tCO_2e) through electrification, followed by urban 12m AC buses (~460 tCO_2e). Across bus length (9m and 12m) and fuel technology (diesel and CNG) variants, Non-AC buses offer lower GHG savings (~50-150 tCO_2e) compared to AC buses (~140-460 tCO_2e) as AC buses have higher energy-efficiency-improvement benefits through electrification. However, Non-AC buses form the majority of buses in India, and they may still pursue electrification due to total-cost-of-ownership (TCO) and energy-security benefits.
2. **Promote electric two- and three-wheelers.** Electrification of two-wheelers and three-wheelers could reduce life-cycle GHG emissions by 28-57% compared to ICE variants. Given that they make up a large portion of India's vehicle fleet (with over 15 million vehicles), accelerating their transition to BEVs avoids lock-in effects[6] and can lead to high aggregate GHG emissions savings. An electric scooter for private use has about 38% lower GHG emissions than a petrol scooter (~1.8 tCO_2e). An electric three-wheeler has 57% lower GHG emissions (~28 tCO_2e) compared to a diesel variant and 41% lower GHG emissions (~15 tCO_2e) than a CNG variant. ICE to BEV transition of scooters is likely to result in higher GHG savings compared to motorcycles, given the higher energy efficiency of ICE motorcycles. Improving the product quality of BEV 2Ws is expected to increase vehicle life and deliver greater GHG benefits in the future.
3. **Encourage a shift in the car fleet towards shared electric vehicles.** Shared cars offer higher decarbonisation potential compared to private cars, on a life-cycle and per-vkm basis. Shared electric cars offer a 50% life-cycle GHG emission reduction compared to an equivalent shared car fuelled by diesel. The reduction in private electric cars compared to private petrol cars is lower at 27% due to fewer usage-km. However, it must be noted that the emissions per pkm for shared electric cars are ~3.9 times that of shared 2Ws.
4. **Choose corridors with high passenger demand for new metro lines.** Metro rail systems have the lowest emissions per passenger-km when using at least 6 000 peak hour peak direction traffic (phpdt) but have relatively high embedded (fixed) emissions in infrastructure and rolling stock. Therefore, meeting ridership targets is crucial in order to realise GHG savings from metro rail systems, suggesting a need for careful corridor selection as well as multimodal and last-mile connectivity.

5. **Mainstream life-cycle assessment into public policy and investment decisions.** Manufacturing contributes up to 37% of life-cycle GHG emissions in the case of BEVs due to the emissions intensity of battery manufacturing. The share of the infrastructure phase within the life-cycle emissions is the highest for 2Ws (~25%), followed by metro rail systems (~22%), private cars (~17%), 3Ws (~16%) and buses (~6%). Infrastructure emissions per passenger-km (pkm) are the highest for private cars (~20 g/pkm), followed by 2Ws (~11 g/pkm), 3Ws (~7 g/pkm), metro rail systems (~5 g/pkm) and buses (~2g/pkm).
6. **Accelerate the transition to battery electric vehicles and complement it with the provision of cleaner energy.** GHG emissions of BEVs are lower than ICE variants across vehicle types as long as the currently-announced clean-energy policy goals are achieved. Even in the Constant energy mix scenario (see Annex A), BEVs have lower GHG emissions across all vehicle types except for 12m Non-AC diesel buses. The IPS scenario, used as a reference case for analysis, assumes that the share of coal-generated electricity in India's grid falls from 73% in 2022 to 51% by 2030 and 21% by 2050. The Net-Zero scenario assumes that the coal share falls to 44% by 2030 and 11% by 2050. No matter what the scenario, this transition will be essential in order for India to maximise the GHG emissions savings possible from electrification.

Annex A.
Life-cycle GHG emissions under India's current energy mix

Life-cycle GHG emissions for India's current energy mix (Constant scenario) for cars and two-wheelers

Mode	Application	Vehicle fuel and technology	Life-cycle GHG emissions (tCO_2e)		Life-cycle GHG emissions per vehicle-km (gCO_2e)		Life-cycle GHG emissions per passenger-km (gCO_2e)	
			ICE	BEV-Constant Energy Mix	ICE	BEV-Constant Energy Mix	ICE	BEV-Constant Energy Mix
Car	Private	Petrol/EV	44.1	37.1	243	204.5	162	136.3
	Shared	Diesel/EV	143.9	83.6	257	150.2	318	185.9
Two-wheeler	Scooter-Private	Petrol/EV	4.8	3.3	74	50.2	74	50.2
	Scooter-Shared	Petrol/EV	7.7	5.1	71	47.6	71	47.6
	Motorcycle-Private	Petrol/EV	4.2	3.3	65	51.2	65	51.2
	Motorcycle-Shared	Petrol/EV	6.7	5.1	62	47.7	62	47.7

Life-cycle GHG emissions for India's current energy mix (Constant scenario) for three-wheelers and buses

Mode	Application	Vehicle technology and fuel	Life-cycle GHG emissions (tCO_2e)			Life-cycle GHG emissions per vehicle-km (gCO_2e)			Life-cycle GHG emissions per passenger-km (gCO_2e)		
			Diesel	CNG	BEV-Constant Energy Mix	Diesel	CNG	BEV-Constant Energy Mix	Diesel	CNG	BEV-Constant Energy Mix
Three-wheeler	Commercial	Diesel/CNG/EV	49	36	24	177	128	85	104	75	50
Urban bus	12m AC	Diesel/CNG/EV	1 303	1 266	1 029	1 548	1 504	1 222	46	44	36
	12m Non-AC	Diesel/CNG/EV	803	896	896	954	1 233	1 064	28	31	31
	9m AC	Diesel/CNG/EV	759	742	742	1 051	1 129	1 028	42	41	41
	9m Non-AC	Diesel/CNG/EV	566	668	628	784	926	869	31	37	35
Intercity bus	12m AC	Diesel/CNG/EV	2 236	2 172	1 515	1 519	1 475	1 029	61	59	41

Annex B. Life-cycle emissions of particulate matter

India faces public-health challenges posed by air pollution from vehicles. Electric vehicles have no tailpipe emissions but the pollution generated by emissions at the power source continues to exist. An analysis of the life-cycle air pollution of ICE and BEV considers particulate matter (PM2.5) emissions as representative of these vehicles' air pollution impact. The life-cycle PM2.5 emissions are based on these vehicles' current and projected emission factors (Source: ICE BS VI[7], BEV-IPS).

The absolute PM2.5 emissions of BEVs were normalised based on their toxicity compared with ICE vehicles, because exposure to PM2.5 from coal power plants is ten times lower than from vehicles (Park et al., 2018)8. The results establish that BEVs have a net reduction in PM2.5 emissions across vehicle types and fuel technologies. Three-wheelers have the maximum net air-pollution reduction impact, followed by two-wheelers, cars and buses. The table above summarises the findings of the analysis.

Life-cycle PM2.5 emissions (adjusted for toxicity implication of BEVs)

Vehicle and fuel mix	Internal combustion engine (kgPM2.5)	Battery electric vehicles – Intended Policy Scenario (kgPM2.5)	Battery electric vehicles – Intended Policy Scenario (kgPM2.5 adjusted for toxicity)	% Particulate Matter reduction due to transition to Battery Electric Vehicles
Private car – Petrol	0.61	3.2	0.32	-48%
Shared car – Diesel	1.60	9.8	0.98	-39%
Private scooter – Petrol	0.22	0.3	0.03	-88%
Shared scooter – ICE	0.36	0.5	0.05	-87%
Private Motorcycle – ICE	0.22	0.3	0.03	-88%
Shared Motorcycle – ICE	0.36	0.5	0.05	-87%
Three-wheeler – Diesel	7.00	3.4	0.34	-95%
12m AC Diesel	16.80	152.1	15.21	-9%
12m Non-AC Diesel	16.80	128.7	12.87	-23%
9m AC Diesel	14.40	110.3	11.03	-23%
9m Non-AC diesel	14.40	90.3	9.03	-37%
12m AC Intercity-Diesel	29.40	225.2	22.52	-23%

Annex C.
Data sources and methodology

Internal combustion engine vehicles: Data sources and methodology for infrastructure emissions calculations

Vehicle type	Occupancy	Life of vehicle	Vehicle weight	Battery	Fuel efficiency
Car	Bengaluru	Secondary data from Delhi derived from UNEP report	Shinde and Sharma, 2023[9]		Secondary data from UNEP
Private two-wheeler scooter	Bengaluru	Consultations with OEMs and vehicle owners	Shinde and Sharma, 2023		TIFAC, forthcoming[10]
Private two-wheeler motorcycle	Bengaluru	Consultations with OEMs and vehicle owners	Shinde and Sharma, 2023		20% better than a scooter
Three-wheeler	Bengaluru	Secondary data derived from Chennai, Visakhapatnam, Gurugram and Udaipur	Shinde and Sharma, 2023		Shinde and Sharma, 2023
Bus 9m	60% of bus capacity (BMTC)	Recent Indian contracts	BMTC	Tata Motors BS IV (Ultra 9.6)	BMTC (Diesel), DIMTS (CNG)
Bus 12m	60% of bus capacity (BMTC)	Recent Indian contracts	BMTC	Ashok Leyland BS IV (Model ALPSV 4/178)	BMTC (Diesel), DIMTS (CNG)

Battery electric vehicles: Data sources and methodology for infrastructure emissions calculations

Vehicle type	Occupancy	Life of vehicle	Vehicle weight	Battery	Fuel efficiency
Car	Bengaluru	Assumed the same as ICE	Shinde and Sharma, 2023	ITF default values	TIFAC, forthcoming
Private two-wheeler scooter	Bengaluru	Consultations with OEMs and vehicle owners	Shinde and Sharma, 2023	Ather 450X	TIFAC, forthcoming
Private two-wheeler motorcycle	Bengaluru	Consultations with OEMs and vehicle owners	Shinde and Sharma, 2023	Revolt RV 400	TIFAC, forthcoming
Three – wheeler	Bengaluru	Consultations with OEMs and operators	Shinde and Sharma, 2023	Piaggio e-city	Shinde and Sharma, 2023
Bus 9m	60% of bus capacity (BMTC)	Recent Indian contracts	Olectra-BYD (Pune)	180 kwH battery	UITP performance evaluation report (2022)
Bus 12m Urban	60% of bus capacity (BMTC)	Recent Indian contracts	Olectra-BYD (Pune)	324 kwH battery	UITP performance evaluation report (2022)
Bus 12m Intercity	60% of bus capacity (BMTC)	Recent Indian contracts	Olectra-BYD (Karnataka)	365 kWh battery	UITP performance evaluation report (2022)
Metro	Bengaluru metro	Detailed Project Reports of Indian metros	ITF default		ITF default

Infrastructure emissions estimates

The emission factors for most phases of the LCA analysis of vehicles are available from secondary literature. However, the secondary literature on the infrastructure phase of the vehicles, particularly in the Indian context, is available only for metro rail systems. Given that the infrastructure phase is a significant contributor to life-cycle emissions, the study used the following approach to derive the likely emissions for this phase for road-based modes of transport:

1. London, a city with mature transport systems in terms of the road network and traffic conditions, is used as a case city to analyse the total road infrastructure (lane-km of roads) available in the city and its usage.
2. Secondary data on the traffic characteristics of London, i.e., mode-wise vehicle-km travelled, is used to derive the annual lane-km used per passenger car. This is extended to derive the lane-km of roads needed over the life of a car.
3. The secondary data on GHG emissions involved in creating a lane-km of concrete urban road is used to derive the life-cycle infrastructure emissions per passenger car.
4. The road infrastructure needs for other vehicle types are derived based on their relative weight compared to cars, with the assumption that the road infrastructure impact of a vehicle is proportional to its weight. Hence the infrastructure emissions for a passenger car are extrapolated to other vehicle types based on their relative vehicle weight.

It is acknowledged that the traffic conditions in London may not represent the most relevant comparison for the Indian context, and the road infrastructure needs may not be exactly proportional to the vehicle weight. However, these assumptions are the best available methodology developed by the authors. Future studies may incorporate more context-specific assumptions to refine the analysis further.

Notes

1. ITF (2021), "Decarbonising India's Transport System: Charting the Way Forward", International Transport Forum Policy Papers, No. 88, OECD Publishing, Paris.
2. https://unfccc.int/sites/default/files/resource/India_LTLEDS.pdf.
3. Further details on the definitions and sources of assumptions used for each of these input variables are provided in the 'ITF India LCA tool': https://www.itf-oecd.org/itf-transport-life-cycle-assessment-india
4. https://www.convergence.co.in/public/images/electric_bus/Grand-Challenge-Case-Study-Final-Web-Version.pdf
5. Number of additional batteries used during the vehicle's life in addition to the one provided at the time of its purchase.
6. Lock-in effects refer to the lock-in of carbon emissions stemming from the inertia created by fossil-fuel-intensive systems that delays the transition to low-carbon alternatives.
7. India adopted Bharat Stage (BS) Emission Standards in 2000, modelled on EU norms. In 2020, India moved from BS-IV to BS-VI, which is at par with the current standards similar to Euro-6/VI norms.
8. Park, M., Joo, H.S., Lee, K. et al. Differential toxicities of fine particulate matters from various sources. Sci Rep 8, 17007 (2018). https://doi.org/10.1038/s41598-018-35398-0
9. Shinde, A. M & Sharma, V. A. (2023). "Life-Cycle Inventory for Road Transport Modes in India". Aapaavani Environmental Solutions Private Limited, Dakshina Kannada, Karnataka, India.
10. Technology Information, Forecasting & Assessment Council (forthcoming), "Estimation of Real Life Fuel Economy of Indian Vehicles by a Data Driven Approach".

Sources

Sources for car, 2W, 3W and metro data: TIFAC (forthcoming), UITP, and stakeholder consultations.

Sources for energy efficiency of buses: Bengaluru Metropolitan Transport Corporation (BMTC) for Urban Diesel, Delhi Integrated Multimodal Transit System Ltd. (DIMTS) for Urban CNG, Karnataka State Road Transport Corporation (KSRTC) Intercity diesel, and on-going trials for hydrogen by Ashok Leyland and Olectra-BYD

Sources for occupancy based on BMTC; life of vehicle based on stakeholder consultations; Energy mix of the Indian electricity grid based on World Bank estimates (yet to be published) and grid emission factors (GEF) calculated by the tool. The assumptions used for the material mix of infrastructure and their GHG emissions are included in the LCA toolkit.

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About this report

The report is the first comprehensive, India-specific analysis of urban passenger transport emissions using a life-cycle perspective. The life-cycle assessment (LCA) approach offers insights into how policy choices affect greenhouse gas emissions throughout vehicle and infrastructure development and use. The analysis shows that Indian cities must prioritise measures that shift private vehicle users to public transport. In addition, a transition to electric buses – preferably powered by 100% renewable energy – is needed. The report highlights the critical importance of analysing and understanding emissions levels through all life cycle stages of transport services when taking public policy and investment decisions.

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