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Life-cycle Assessment of Passenger Transport: An Indian Case Study

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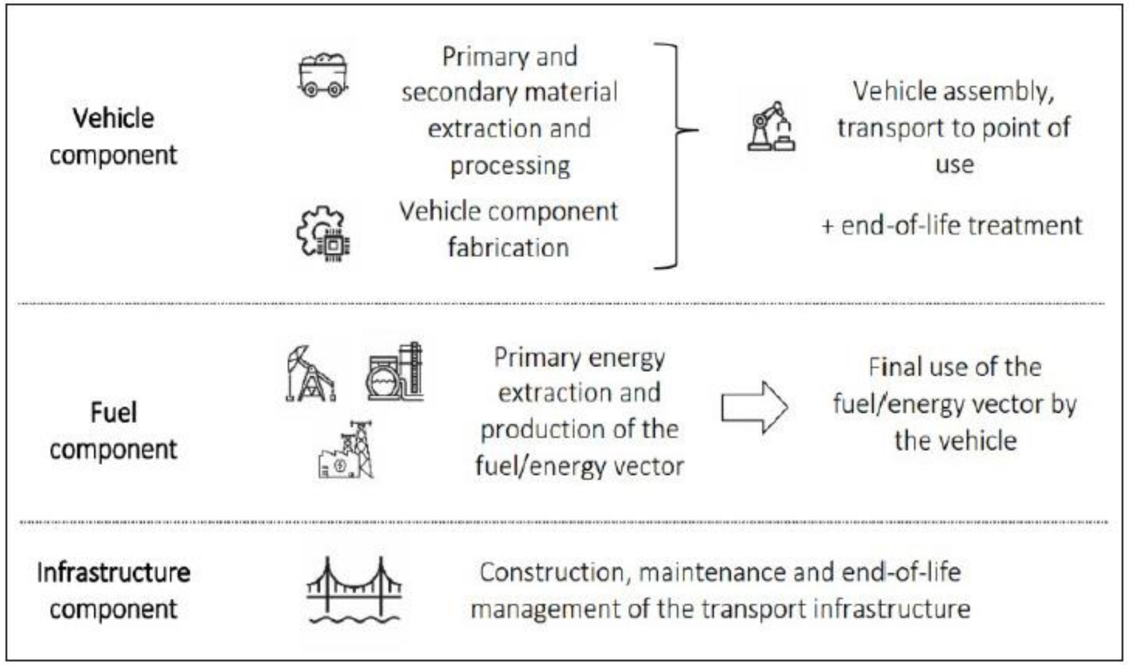
ITF Transport Life-cycle Assessment Tool for India



- **Manufacturing**, including the **assembly and disposal** of the vehicle and battery
- **Transport** of the vehicles
- **Use** of the vehicles, including **energy production**
- **Operational services** needed by specific vehicles
- **Infrastructure construction and maintenance**

Scope

- The tool focuses on vehicle level analysis and doesn't consider economy-wide mode-share scenarios

Passenger transport	Vehicle technologies	Fuels	Life-cycle phases
• Private and shared transport modes (cars including taxis and ride-hailing services, such as Uber or Ola and two-wheelers) • Public transport modes (three-wheelers, buses and metro-rail systems)	• Internal combustion engines (ICE) • Battery electric vehicle (BEV) • Fuel cell electric vehicle (FCEV)	• Diesel • Petrol • Compressed natural gas (CNG) • Blue hydrogen (CNG based) • Green hydrogen (100% renewable energy based)	• Vehicle and battery manufacturing • Transporting the vehicle to the point of sale • Vehicle usage • Related infrastructure

Energy scenarios

Intended Policy Scenario (IPS)	• The 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	• The buses being powered entirely by RE.

Additional Scenarios

A scenario for battery electric intercity buses powered by 100% renewable energy, comparing them with hydrogen-powered intercity buses.

A constant scenario which assumes the current energy mix to remain the same in the future.

Outputs

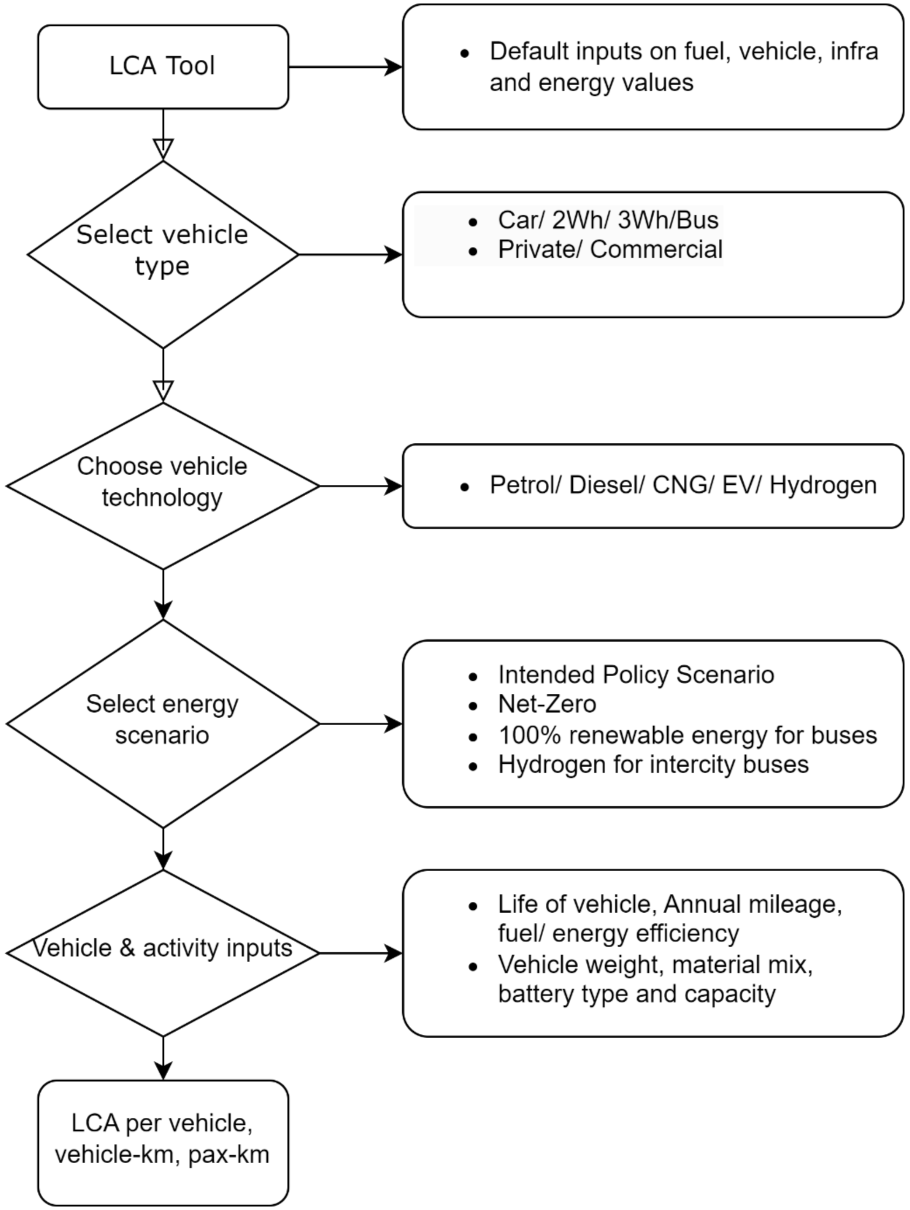
Total GHG emissions of the vehicle over its lifetime

Average GHG emissions per passenger kilometre (pkm) travelled.

Average GHG emissions per vehicle kilometre (vkm) travelled.

LCA analysis: Process flow

- The lifecycle emissions are the sum of GHG emissions from four key phases of the vehicle.
    - Vehicle and battery manufacturing
    - Transporting the vehicle to the point of sale
    - Vehicle usage
    - Operational services and Infrastructure
- India specific assumptions for each of these phases were derived through a combination of stakeholder consultations, secondary literature and the GREET model
- LCA tool now has default input values for the most popular modes and their vehicle models in India/ South Asia
- Users need to choose the vehicle type, technology, energy scenario and activity details based on context for analysis

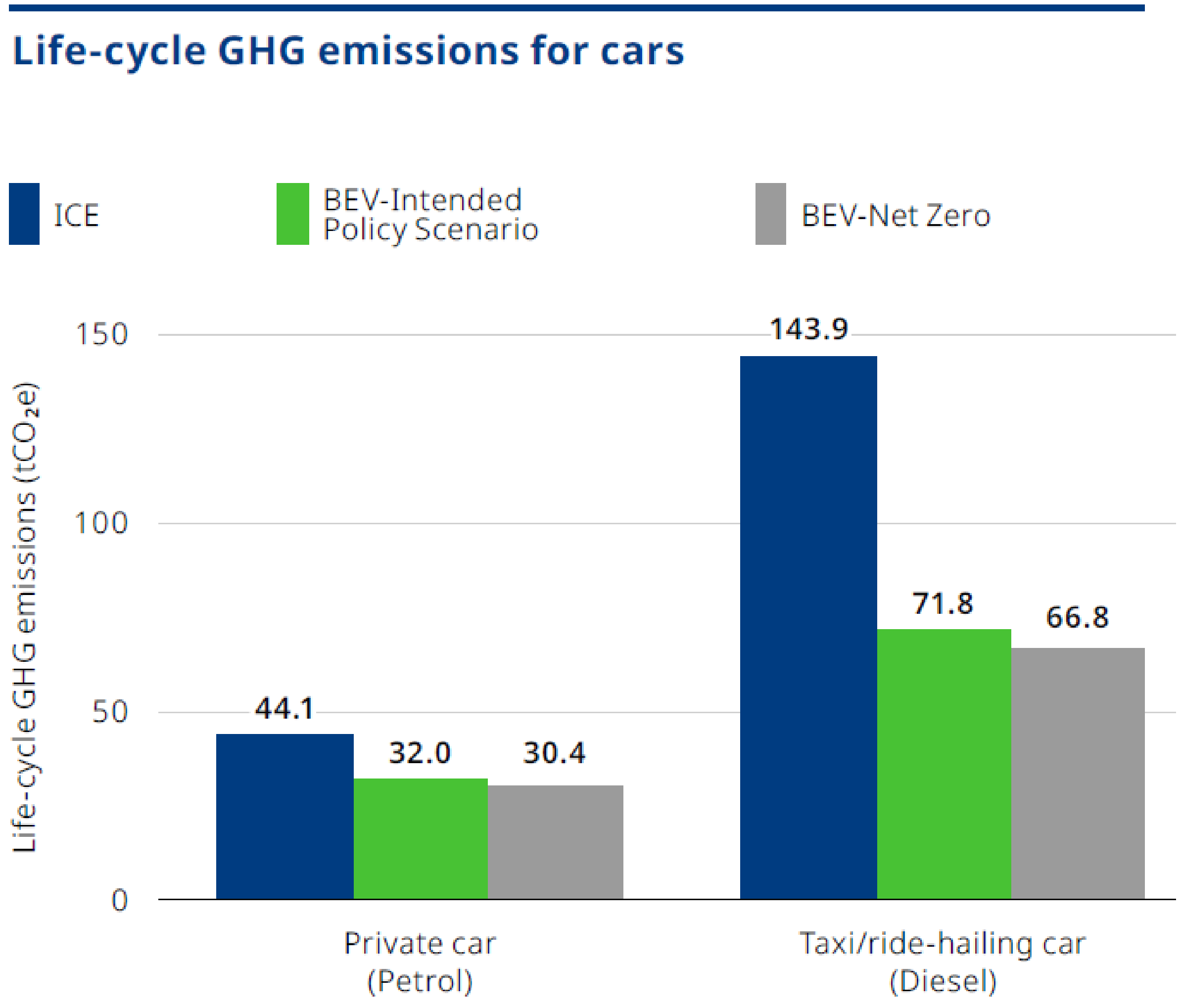


Lifecycle GHG emissions for Cars

- BEV personal cars will have lower lifecycle GHG emissions compared to ICE (petrol) cars by ~12.1-~13.7 tCO_2e across energy-mix scenarios

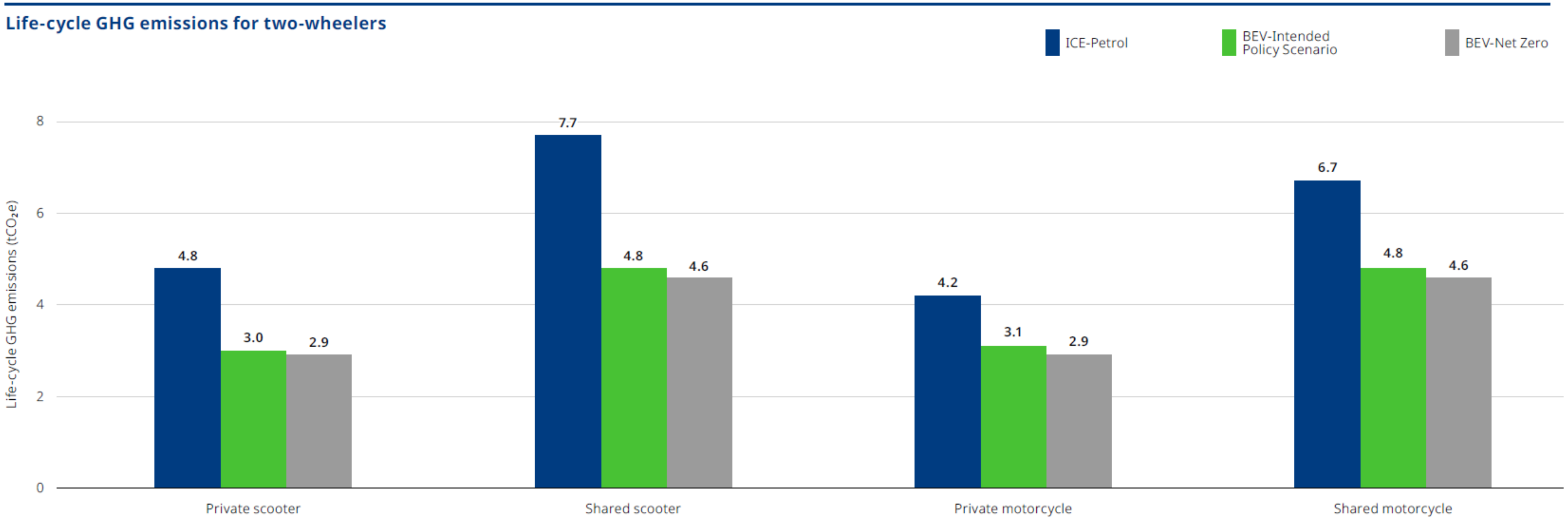
- Shared cars used as taxis/ ride-hailing served have significantly higher savings of ~51-68 tCO_2e across energy-mix scenarios

- Lifecycle GHG emissions of taxis/ ride-hailing are 3 times of personal cars for ICE variants but only ~2.2 times for BEVs as BEVs are more energy efficient



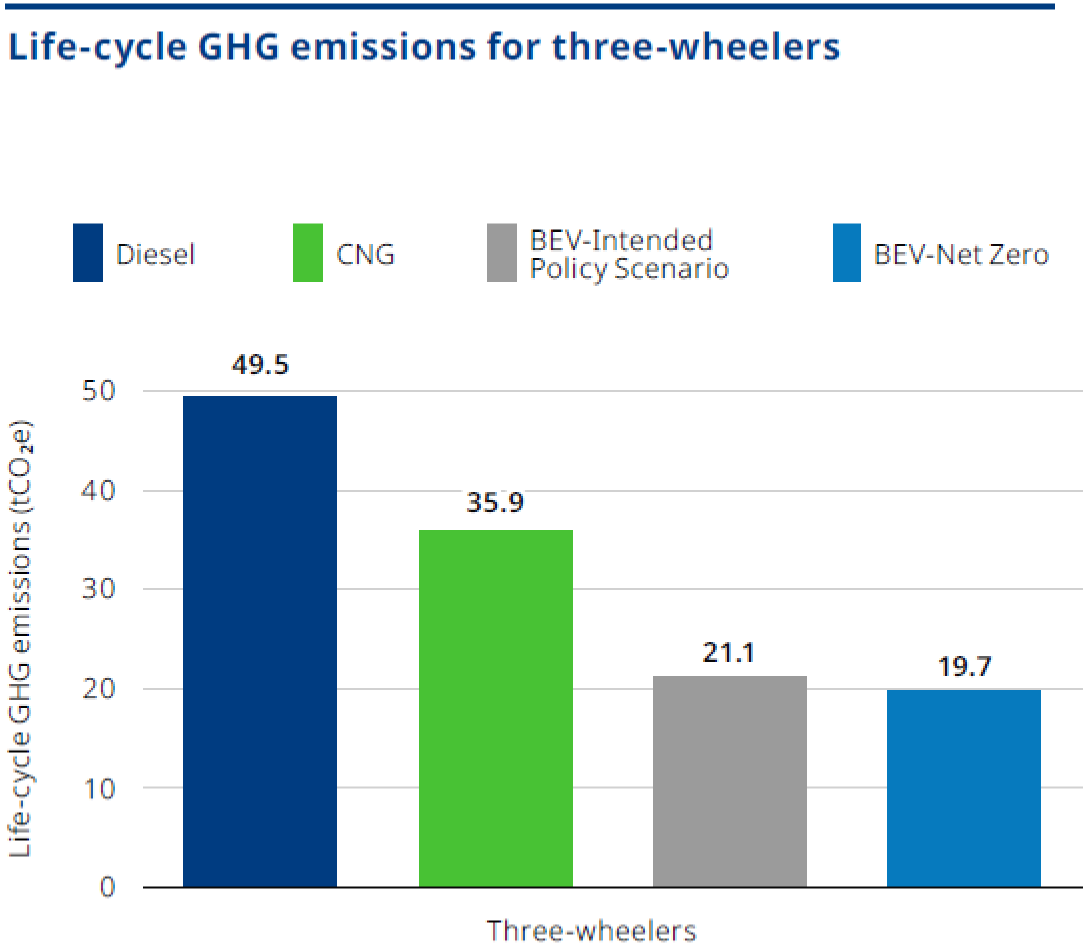
Lifecycle GHG emissions of 2-wheelers: Scooters, Motorcycles

- ICE (petrol) motorcycles have better performance than scooters due to better energy efficiency whereas for BEVs, scooters are more efficient due to smaller batteries and lesser manufacturing related emissions
- Transitioning personal scooters and motorcycles from petrol to electric technology can reduce their lifecycle GHG emissions by ~1.1-1.9 tCO_2e across BEV scenarios
- Shared scooters and motorcycles can save between ~1.9-3.1 tCO_2e depending on the use-case and energy scenarios



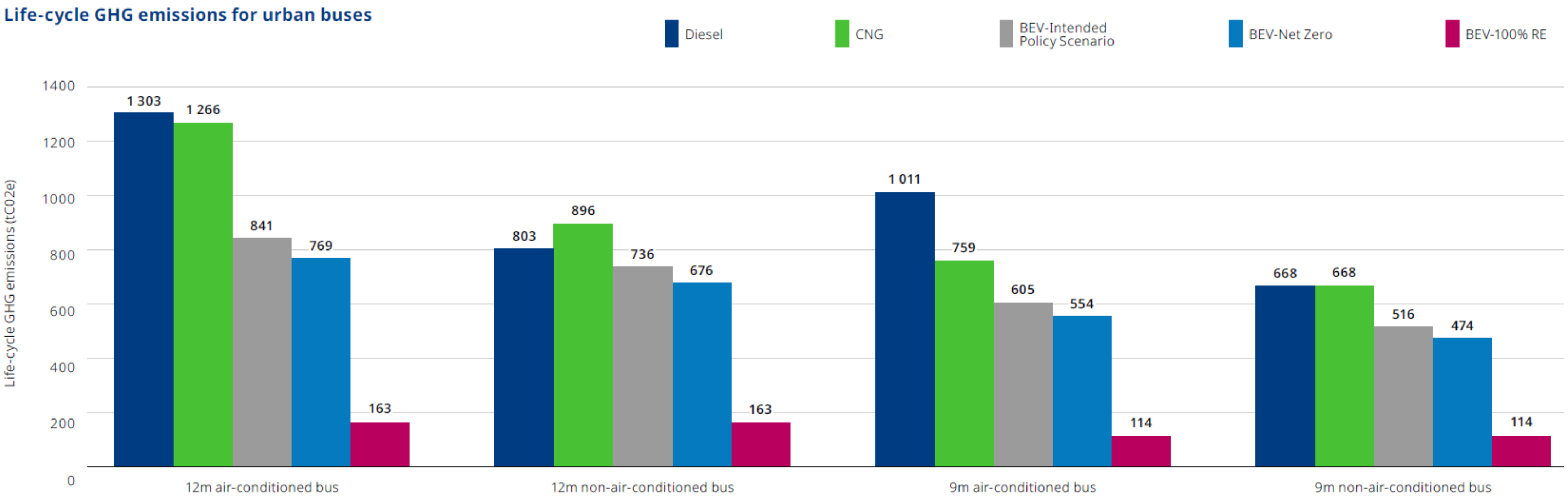
Lifecycle GHG emissions for 3-wheelers

- 3Ws deliver substantial benefits through transition to BEVs due to a combination of better energy efficiency and high operated-km per day
- Each diesel 3W transition to electric can save ~28.4-~29.8 tCO_2e of GHG savings across energy scenarios
- CNG to electric transition 3Ws would deliver ~14.9 to ~26.2 tCO2e savings per vehicle
- Even the per vkm and per pkm emissions would reduce by 33-57% depending upon the energy mix scenario



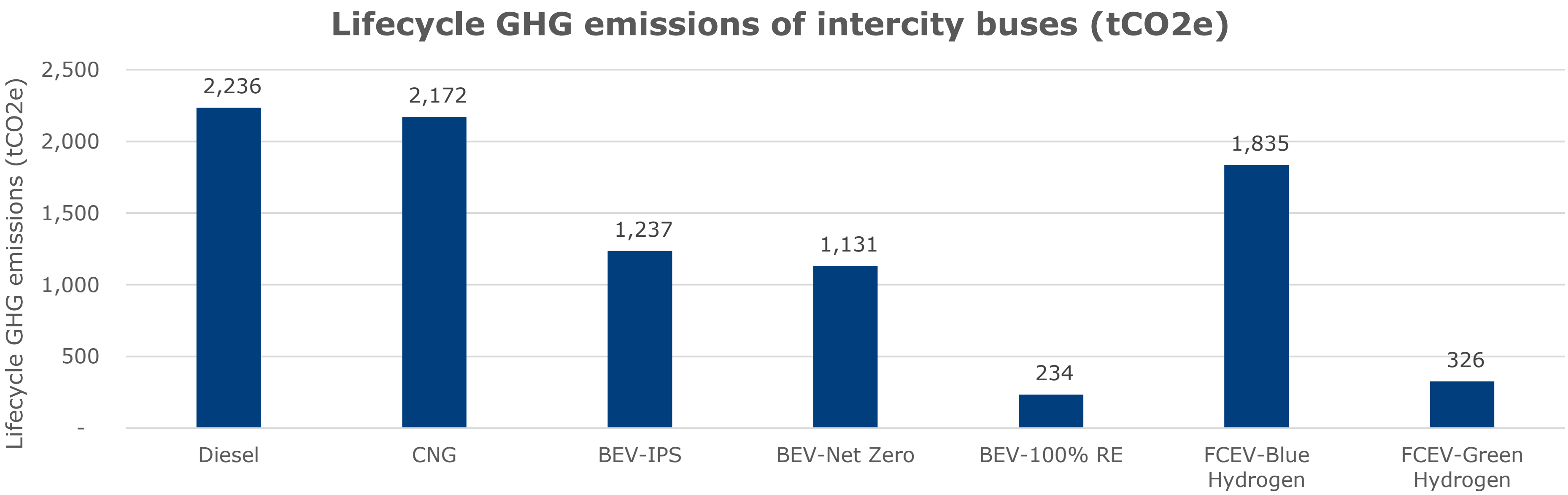
Lifecycle GHG emissions for urban buses

- Electric AC buses offer ~400 to ~535 tCO_2e lower GHG emissions compared to diesel buses across bus types (9m, 12m) and ~200 to ~500 tCO_2e savings compared to CNG
- Electric Non-AC buses save anywhere between ~70 to ~200 tCO_2e emissions as the energy efficiency difference between ICE and electric buses is much lower
- In case cities procure Renewable Energy (RE) for bus operations, the savings can be between ~400 tCO_2e and ~1,100 tCO_2e across bus types and energy scenarios



Lifecycle GHG emissions for intercity buses

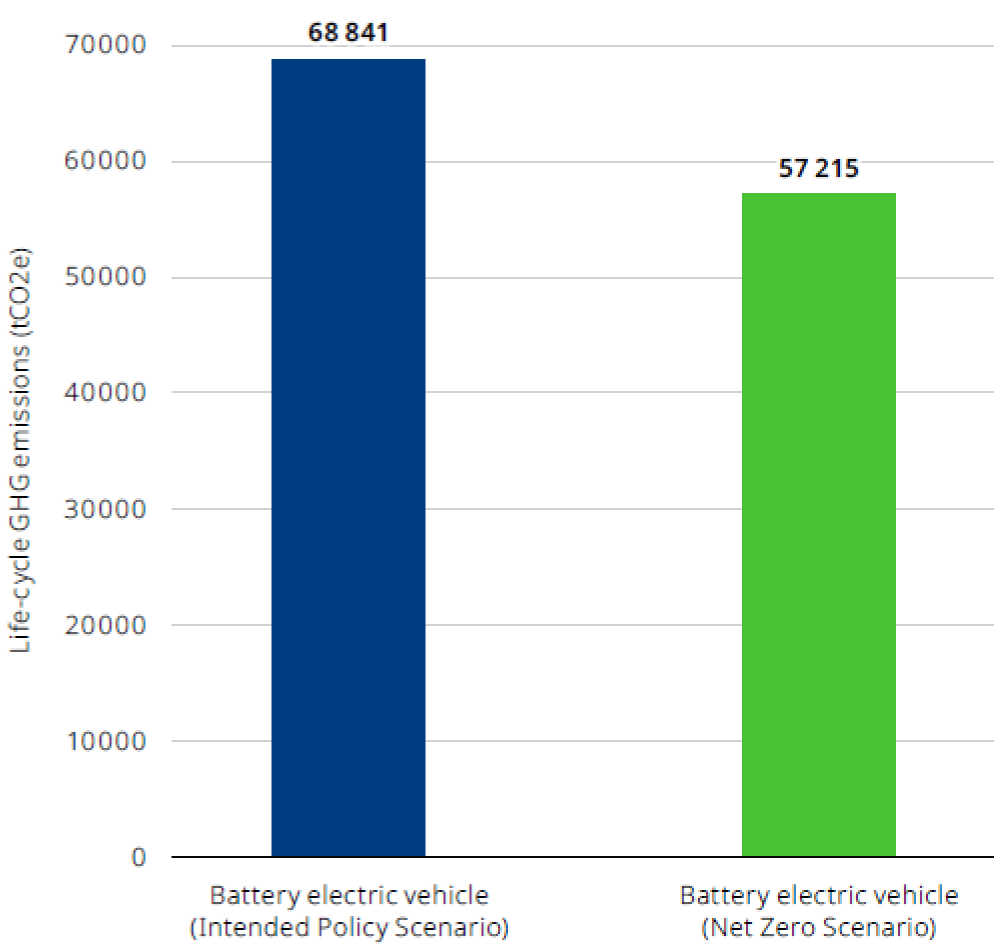
- LCA of Intercity buses of 12m AC variety were analysed for GHG impact transition to Battery Electric Vehicles (BEV) as well as Fuel Cell Electric Vehicles (FCEV). FCEV buses are analysed for two sources of Hydrogen: Blue hydrogen (CNG based) and Green hydrogen (100% renewable electricity (RE))
- E-bus deployment along intercity routes can reduce lifecycle emissions by ~935 to ~1,100 tCO_2e, i.e. ~45-50% lower life-cycle GHG emissions compared to diesel/ CNG buses
- Blue hydrogen based buses can save only ~324 to ~388 tCO_2e which is lower than urban bus savings. Green hydrogen can deliver up to ~1,900 tCO_2e but has higher emissions than 100% RE due to electrolysis linked emissions



Lifecycle GHG emissions for metro rail systems

- Metro rail systems can potentially deliver savings of ~11,600 tCO_2e over their 50 year lifecycle assuming average demand of 6,000 peak hour per direction trips (phpdt)
- However, they also have embedded emissions of ~10,900 tCO_2e per one-way track
- 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
- If demand reaches 15,000 phpdt the embedded emissions per passenger-km are lower than buses

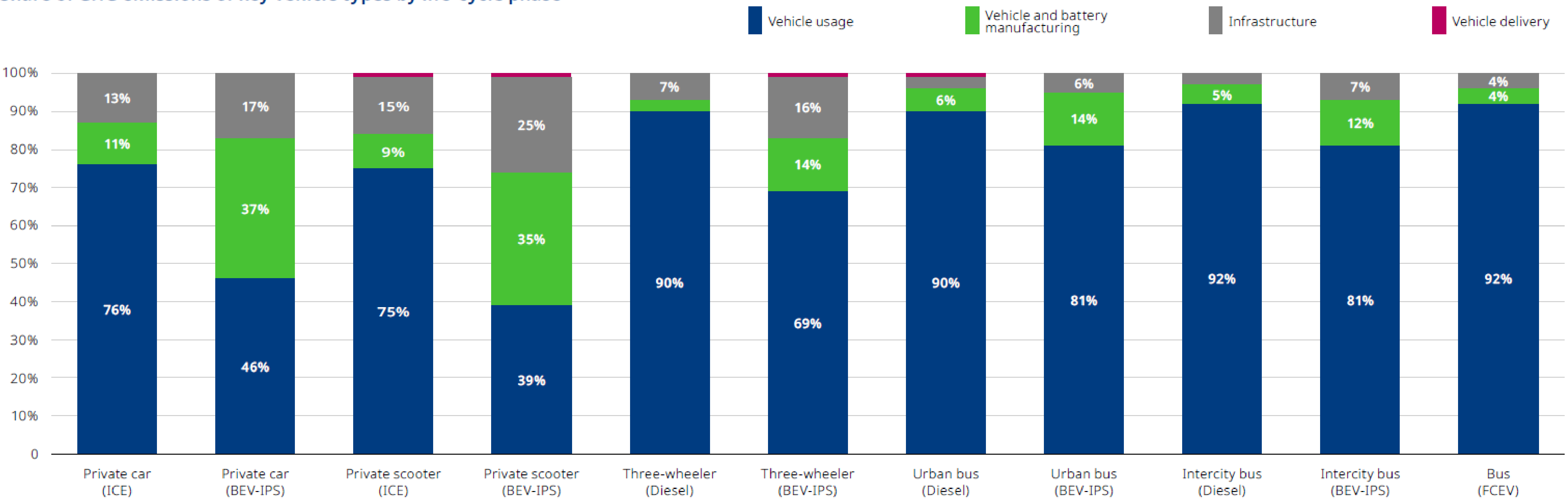
Life-cycle GHG emissions for a six-car metro train



Phase-wise share of GHG emissions

- 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%)
- Manufacturing phase emissions are higher for private vehicles due to their limited lifecycle vehicle-kms

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



Air-quality impact of vehicle technology choices

- BEVs have a net reduction in $PM_{2.5}$ emissions across vehicle types and fuel technologies because exposure to $PM_{2.5}$ from coal power plants is ten times lower than from vehicles
- Electrification of three-wheelers have the maximum net air-pollution reduction impact, followed by two-wheelers, cars and buses

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%

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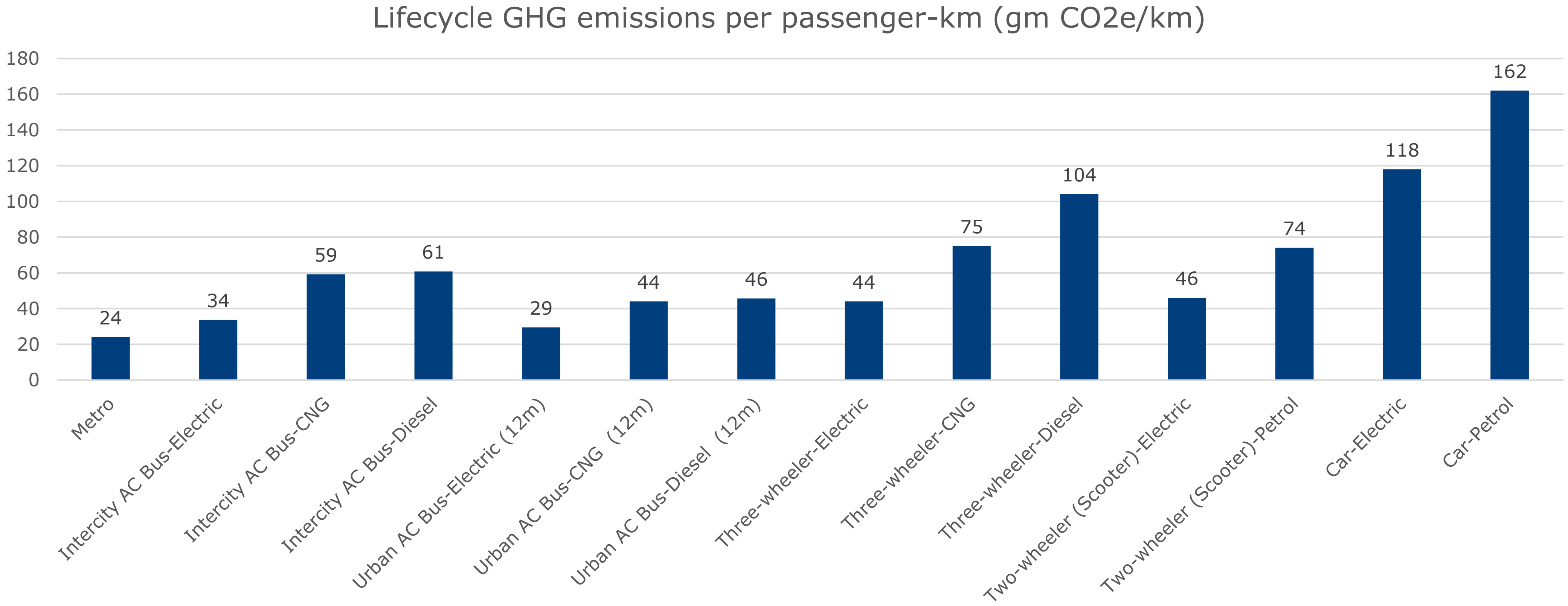
Mode-wise GHG emissions per passenger-km

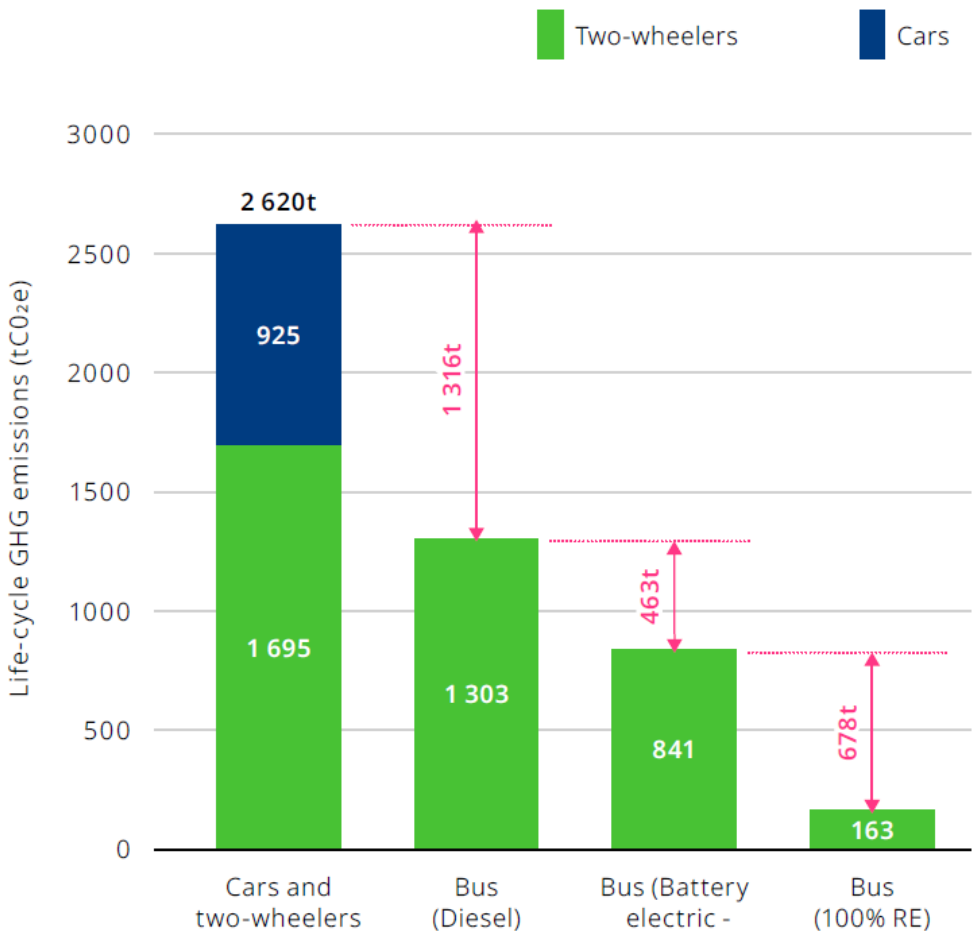
- Metro rail systems have the least GHG emissions per-km, assuming a minimum demand of 6,000 phpdt
- Within electric vehicles, e-buses have the least emissions per pax-km, i.e., at least ~24% lower the e-2Ws and e-3Ws, 71% lower than private cars, and 79% lower than shared cars
- Emissions per passenger-km are for ride-hailing cars due to deadheading between trips



Urban mobility policy choices based on LCA results

- Mode-shift analysis is caried out assuming a 20:80 ratio of Car: 2W usage among private vehicles
- The maximum reduction in GHG emissions in urban passenger transport would be delivered by encouraging users of cars and 2Ws to switch to buses, even ICE buses, as this is likely to deliver a GHG reduction of ~1,300 tCO2e per bus over its 12 year life
- The technology transition from diesel to electric in the IPS scenario will deliver ~460 tCO2e GHG emission savings over the life of the bus
- Powering these buses by 100% renewable energy (RE) will deliver a further reduction of ~680 tCO2e in GHG emissions over the life of the bus
- Cities pursuing a combination of (a) mode shift to buses and (b) electrification of buses (powered by 100% renewable energy) can potentially generate a total of ~2,450 tCO2e in GHG savings during the life of a bus.

Life-cycle GHG emissions for urban buses (tCO_2e)



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Recommendations

- Initiate a modal shift from private vehicles 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
- Accelerate the transition to battery electric vehicles and complement it with the provision of cleaner energy
- Mainstream lifecycle assessment into public policy and investment decisions

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Thank you

Link to LCA tool and report:

https://www.itf-oecd.org/itf-transport-life-cycle-assessment-india

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