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CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

THE POTENTIAL TO ELECTRIFY FREIGHT TRANSPORTATION IN INDIA

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Background

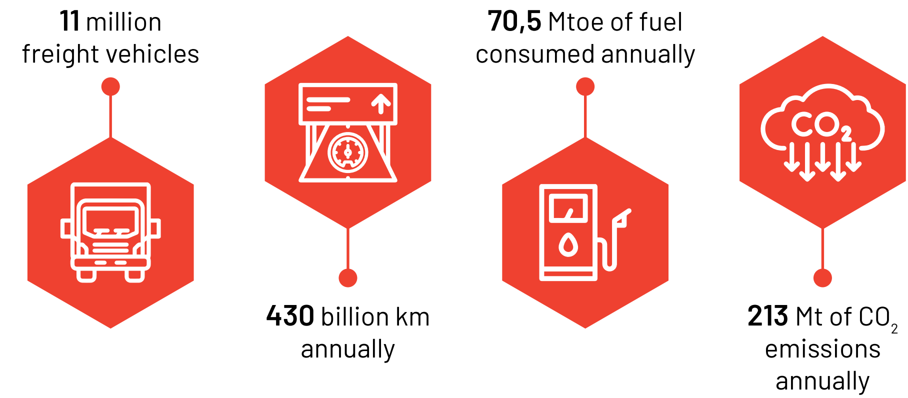
Over two-thirds of Indian goods are transported on roads. About 11 million freight vehicles carry 2.1 trillion tonne-km of freight annually (Bernard Aritua et al., 2018). These vehicles are largely dependent on fossil-based fuels (90% is diesel) for their movement (NITI Aayog et al., 2021). The road freight sector consumes about 70.5 million tonnes of oil equivalent (Mtoe) and emits 213 Mt of CO_2 annually. Thus, it accounts for approximately 53% of the country's transport fuel consumption and about 54% of CO_2 emissions.

With improving standard of living, increasing consumerism, and growing e-commerce, the freight movement is expected to increase exponentially in the coming decades. Recognising the potential growth of freight vehicles, their demand for fuel, and the resultant impact on the environment and public health, decarbonisation of freight transport should be a priority. This is crucial to meet India's target of reducing CO_2 emissions by 1 billion tonnes by 2030 in order to achieve net-zero carbon targets by 2070 (BBC News Services, 2021).

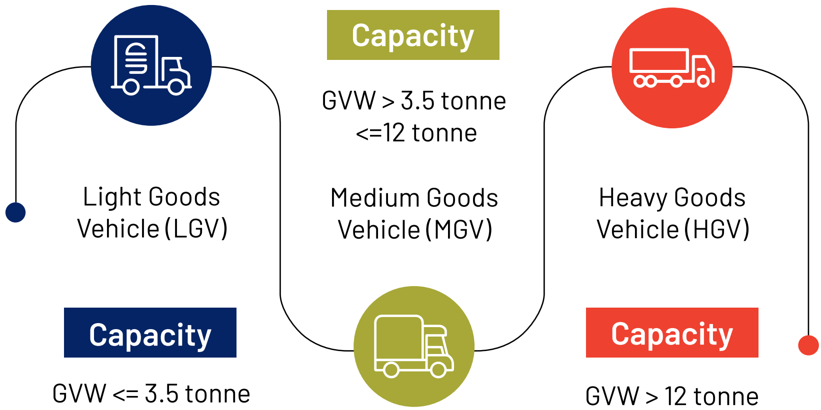
While the most energy-efficient decarbonisation strategy is to shift the mode of freight transport from road to rail, this solution is not very feasible in India. This is mainly due to lack of wide-spread rail infrastructure and poor last-mile connectivity. This forces India to look at cleaner vehicle technologies (like battery and fuel cell electric vehicles (EVs)) for road movement of freight as a feasible decarbonisation strategy.

In this note, we aim to assess the potential benefits of electrifying freight vehicles in India.

The Freight Footprint



Freight vehicles in India are classified on the basis of their gross vehicle weight (GVW) as light, medium, and heavy goods vehicles. Among the 11 million freight vehicles, light goods vehicles (LGVs) dominate the vehicle stock with 56% of the share, followed by heavy goods vehicles (HGVs) contributing 38% (Vahan, 2021) (Figure 1). These freight vehicles account for 213 Mt of CO_2 emissions annually. HGVs contribute to 83% of these emissions while accounting for only 38% of the total freight vehicle stock (Figure 1).



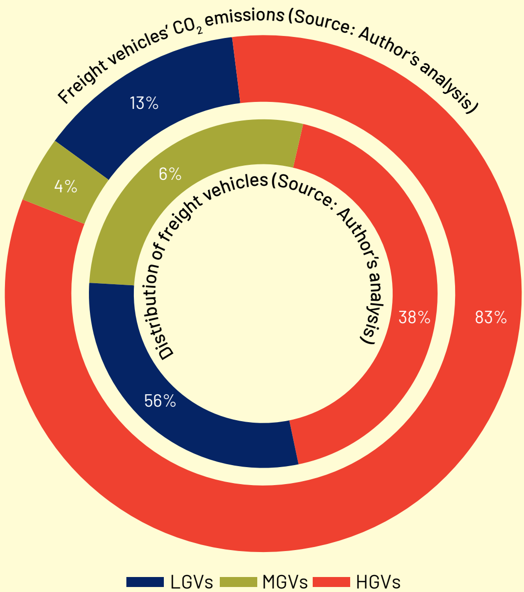


Figure 1: Distribution of freight vehicles' stock and emission contribution

Collectively, these freight vehicles travel about 430 billion kilometres annually (Figure 2) and consume 80.7 billion litres of fuel (Figure 3), with diesel accounting for 90% of it. HGVs travel more annually and consume more fuel than LGVs and MGVs (due to poor fuel efficiency).

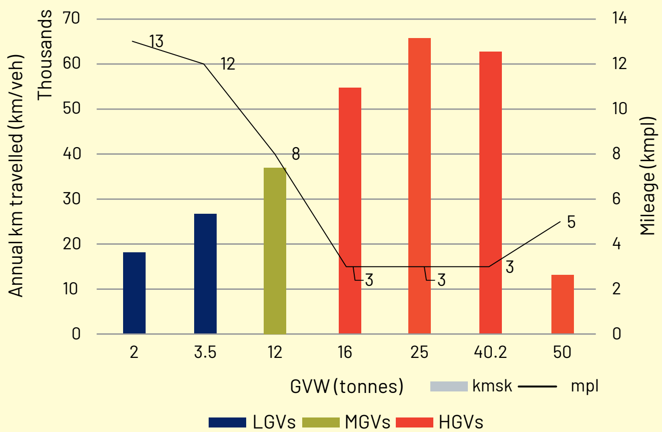


Figure 2: Annual vehicle km travelled and mileage of freight vehicles (Source: Author's analysis)

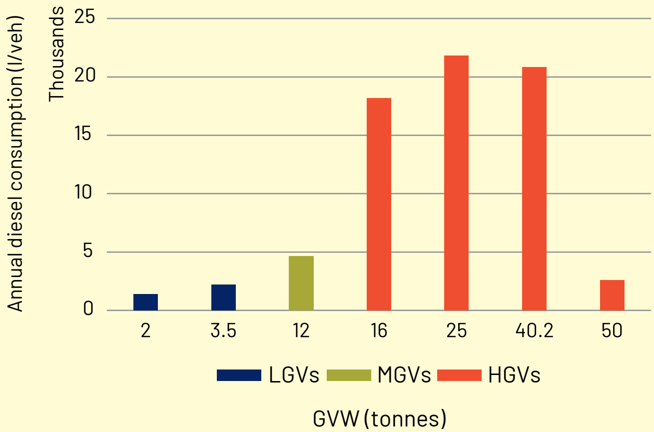


Figure 3: Annual diesel consumption of vehicles

This magnitude of environmental impact warrants immediate action to electrify freight transport.

Benefits

Scenarios

Base Scenario: Electrification of passenger transport only by 2030

Slow Electrification Scenario: Electrification of passenger transport + slow electrification of freight transport by 2030

Fast Electrification Scenario: Electrification of passenger transport + fast electrification of freight transport by 2030 transport only by 2030

Benefits

Annual savings in 2030 compared to Base Scenario	Slow Electrification Scenario (0.2% reduction)	Fast Electrification Scenario (4% reduction)
CO_2 emissions (Mt of CO_2)	2.3	55.6
Fuel savings (million litres)	825	21,000
Fuel costs (Cr INR)	7,000	1,75,000

In order to estimate the potential benefits of freight electrification by 2030, three scenarios have been considered and explained in Box 1.

Scenarios for Freight Electrification by 2030

Base Scenario: Electrification of passenger transport only
Adoption of EVs in passenger transport according to the projections by NITI Aayog. No policies to promote electrification of freight vehicles is considered in this scenario.

Slow Electrification Scenario: Electrification of passenger transport + slow electrification of freight transport
Adoption of EVs in passenger transport according to the projections by NITI Aayog. This scenario considers a slow adoption of EVs in freight transport – 1.6%, 0.08%, and 0.07% EVs in the LGVs, MGVs, and HGVs categories, respectively – according to the IEA EV Outlook, 2021.

Fast Electrification Scenario: Electrification of passenger transport + fast electrification of freight transport
Adoption of EVs in passenger transport according to the projections by NITI Aayog. This scenario considers a fast adoption of EVs in freight transport, with 30% EVs in LGVs and 5% in the MGVs and HGVs categories.

Box 1: Scenarios for freight electrification by 2030

The electrification of LGVs has already gained momentum in India with 0.03% e-LGVs. This is on account of many e-commerce and logistics companies willing to convert their fleet to cleaner vehicle technologies to save costs and contribute to emission reduction. Hence, LGVs are expected to contribute to a larger share of EVs in comparison to other freight vehicle categories.

The resulting share of EVs in the total stock for the three scenarios is illustrated in Figure 4 and resultant growth of freight EVs between 2019 and 2030 is shown in Figure 5.

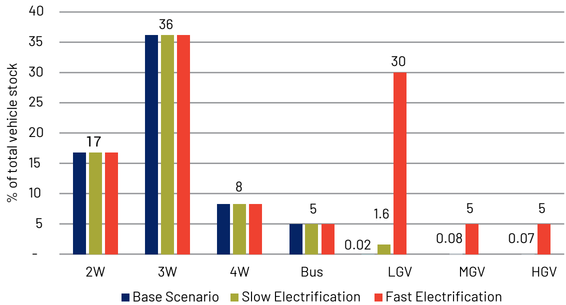


Figure 4: Share of EVs in total vehicle stock in 2030 (Source: Author's analysis)

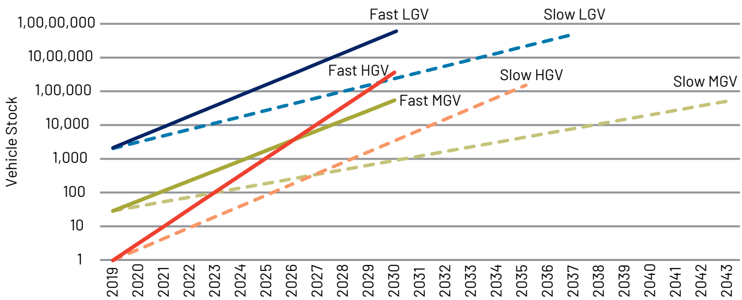


Figure 5: Growth of freight EVs in slow and fast electrification scenarios (logarithmic) (Source: Author's analysis)

Using these projections, the potential benefits of freight electrification by 2030—in terms of fuel saved and emissions reduced—are estimated. The methodology adopted for the estimation is discussed in Annexure 2.

Projected Fuel Savings

In comparison to the base scenario, the slow electrification of freight would save about 825 million litres of fuel (and INR 7,000 crore) and fast electrification would save ~21,000 million litres (and INR 1.7 lakh crore)[1] annually in 2030 (Figure 6 and Figure 7).

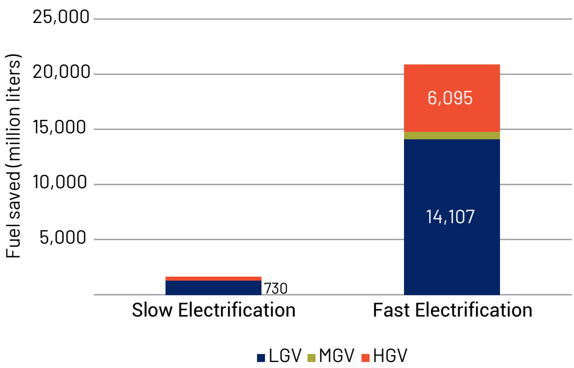


Figure 6: Annual fuel saved in 2030 (Source: Author's analysis)

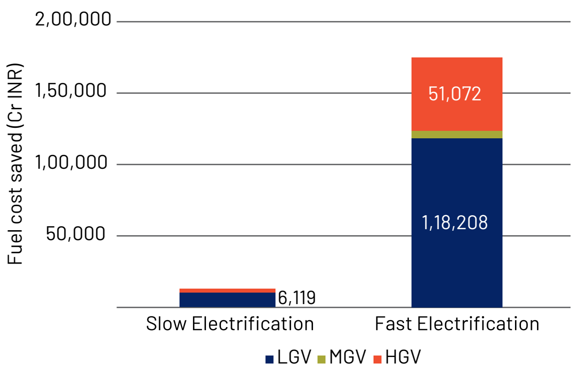


Figure 7: Annual saving on fuel cost in 2030 (Source: Author's)

1 Assuming the base price of diesel in 2030 would be INR 83.8 per lit.

Projected CO_2 Emissions Reduction

By keeping in check fuel consumption, CO_2 emissions can also be reduced. The slow electrification of freight can reduce about 2.3 Mt of CO_2 emissions and faster adoption can help reduce up to 56 Mt of CO_2 emissions (Figure 8).

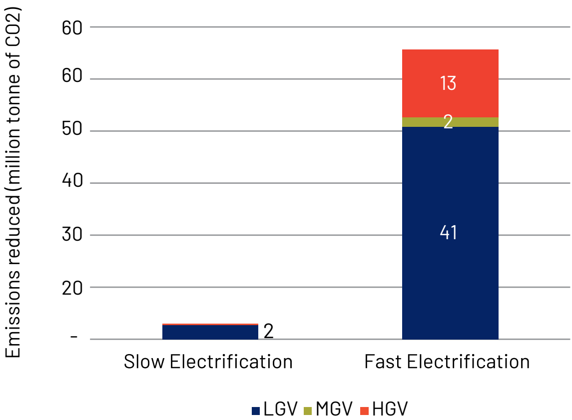


Figure 8: Annual CO_2 savings in 2030 (Source: Author's analysis)

Apart from the reduction in fuel consumption and CO_2 emissions, electrification of freight can also lead to reduction in operational costs. Using the WRI India TCO Evaluator (WRI India, 2020), it was found that by replacing diesel vehicles with EVs, the fleet operators can save between 24% (for HGVs) and 48% (for MGVs) of the operational costs (Figure 9).

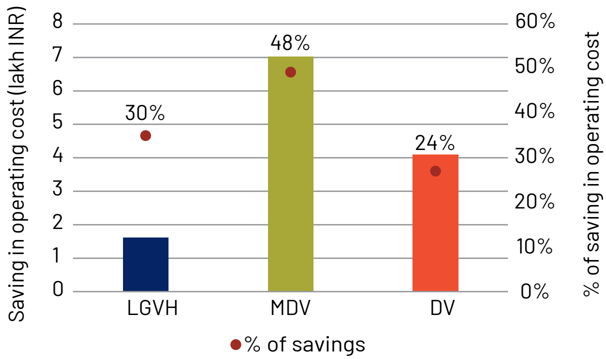


Figure 9: Annual savings in operating costs of each vehicle (Source: Author's analysis)

The analysis shows that significant benefits can be realised from the faster electrification of freight.

Comparison with Passenger Transport

Comparing these benefits of freight transport electrification with that of passenger transport, shows (Figure 10) that

- Electrifying 30% of the LGVs by 2030 would lead to a reduction of 41 Mt of CO_2 (i.e., 305 g CO_2/km travelled by an LGV). **This is 7 times more emission reduction realised by converting a kilometer of 2W movement to electric and 3 times that realised by converting a kilometer of 4W movement.**

- Electrifying 5% of the HGVs by 2030 would lead to a reduction of 13 Mt of CO_2 (i.e., 609 g CO_2/km travelled by an HGV). **This is 14 times more emission reduction realised by converting a kilometer of 2W movement to electric and 6 times that realised by converting a kilometer of 4W movement.**

- While a 5% electrification of MGVs can reduce upto 876 g CO_2/km travelled, the cumulative benefits are comparatively less (only 2 Mt of CO_2). This is due to lower utilisation of MGVs as compared to LGVs and HGVs in India.

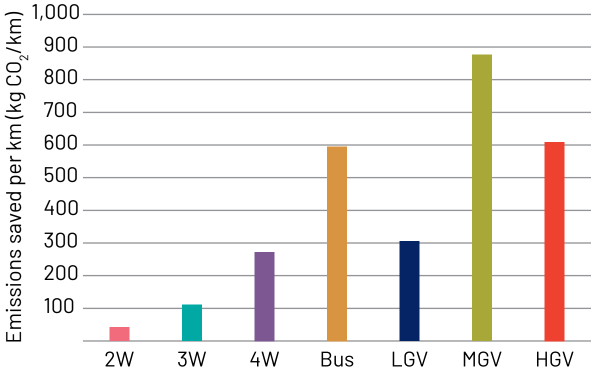


Figure 10: Comparison of CO_2 savings from various vehicle categories (Source: Author's analysis)

A case for E-HGVs

In India, HGVs accounting for as little as 2% of the total vehicle stock and 10% of the vehicle kilometer driven contribute to ~43% of the CO_2 emissions annually. In contrast, the two-wheelers in India account for 77% of the total vehicle stock and are responsible only for ~11% of the CO_2 emissions (Figure 11). This makes long haul freight transport through HGVs the prime candidate for electrification.

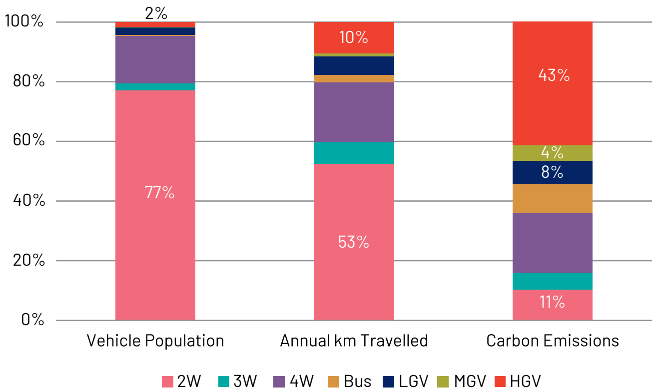


Figure 11: Emissions from freight vehicles as compared to all road transport vehicles (Source: Author's analysis)

Opportunities

Range: The global average range provided by electric HGV models is around 400 km (International Energy Agency, 2021). Given that the average daily km-run by HGVs is around 400 km in India, range anxiety is negligible.

Speed: Technically, EV batteries attain better performance (optimal energy consumption and driving range) at the speed of 35–40 kmph, and average speed of trucks in India is as low as 25–40 kmph, making them a good choice for electrification.

Government Initiatives: The Ministry of Road Transport and Highways (MoRTH) and other state transport authorities plan to develop EV-friendly highways—Delhi–Jaipur (Sabyasachi Dasgupta, 2021), Mumbai–Pune, and Bengaluru–Mysuru (Shrinivasa M, 2021)—with extensive charging infrastructure. The Department of Heavy Industry (DHI) also suggests installing public charging infrastructure at every 25km along all Indian highways.

Barriers

High Energy Consumption: The electricity consumption of trucks is 37% higher than 2Ws, 18 % higher than 3Ws, and 8% higher than 4Ws. This would have significant impact on the power grid infrastructure (to the extent of 47.3 Terra Wh more under the fast electrification scenario).

Infrastructure: The current charging infrastructure is sparse, with a focus on installing low-power rated chargers (up to 50 kWh). HGVs would require high-power rated chargers, which are also expensive.

Emissions: Higher well-to-tank emissions compared to ICE vehicles (1.5 times even at 55% coal mix target with lower grid emission factor by 2030) reduce the potential of emission savings through e-HGVs (Refer to Annexure 2).

Capital Cost: High capital cost of vehicle and battery replacement due to need for large battery size (at least 250 kWh).

Large Batteries: These would reduce the payload the e-trucks can carry, thereby, impacting the revenue.

Market Readiness: Even with a few pilots (Livemint, 2021; News18, 2021), the Indian market is not ready and has limited e-truck models to electrify the HGV segment. Currently, India has to rely on foreign markets for these vehicles, which would increase the capital cost.

Strategies for Freight Electrification

Financial Solutions

Purchase Incentives: The current FAME subsidy provided for passenger vehicles (Scheme for Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II), 2019) should be extended to freight vehicles as well. The subsidy provided for light passenger vehicles—i.e., INR 10,000/kWh—can be provided for LGVs, and that provided for e-buses—i.e., INR 20,000/kWh—can be provided for HGVs. Similarly, the existing tax rebates on EVs should cover the freight vehicles also.

Support Domestic Market: Local supply should be promoted through manufacturing mandates like those followed in most parts of China and California in the USA (California Air Resources Board, 2021). This could reduce the cost of the vehicles, thereby making their total cost of ownership (TCO) more competitive than that of conventional vehicles. The government should encourage investments in battery and vehicle technologies innovations that might reduce vehicle costs.

Infrastructure Solutions

Fast and Ultrafast Chargers: These freight vehicles require high-power rated chargers to sustain their operations. For smaller and short-haul vehicles, chargers at terminals or warehouses would suffice, but larger and long-haul vehicles might require intermittent fast charging to continue operations. While LGVs would require DC chargers of 50 kW or AC chargers of 3.3 kW, MGVs would require DC chargers of 50–100 kW, and HGVs would require more powerful DC chargers of 120–200 kW for single-time charging (BYD, 2021). For instances where intermittent charging would be required, chargers above 200 kW (ultra-fast chargers) or even up to 1 MW (megawatt chargers) should be installed.

Grid Reinforcements: Given the need for such high-power rated chargers, some charging stations for long-haul freight movement might require power of up to several GW. This requires infrastructure development that is well-coordinated among power generators, distribution companies, and charger operators. Since the electricity demand from EVs is expected to increase on account of freight electrification, it is also important to increase the share of renewables in the energy mix to reap the benefits of CO_2 reduction.

Network of Chargers: To address the charging demand of these freight vehicles, especially on highways, charging stations should be placed 80 km apart in the short term. The density can be eventually increased (to avoid extra waiting times), with stations at 25 km intervals in the long term.

Implementation Solutions

Planning of EV Highways/Corridors: Special highways or segments of the highways can be designed as EV highways, such as the proposed Delhi–Jaipur (Sabyasachi Dasgupta, 2021), Mumbai–Pune, and Bengaluru–Mysuru (Shrinivasa M, 2021) EV corridors.

These corridors can be developed where:

a. There is a significant freight traffic on account of extensive industrial and commercial activities.

b. The routes are 200–250 km long.

c. Freight hubs with charging infrastructure are available at every 100 km, for full battery charging.

d. The vehicles are able to maintain an average speed of 60 kmph.

e. There is no significant elevation change.

Urban Freight Demonstrations: Some cities can be chosen to demonstrate and observe the benefits of freight electrification by promoting the use of e-LGVs. The e-LGVs can be operated on routes that are up to 100 km long, follow a hub-and-spoke model to enable charging at common locations frequently, and have sufficient charging infrastructure at the hubs.

Low Emission Zones: Zones within cities should be demarcated as low emission zones that permit only low/zero-emission vehicles to ply. This would encourage the adoption of EVs by urban freight operators.

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Annexure 1: Case studies and their impact on environment

Country/Study	Type	Vehicle Category	Year of Implemenation	Features of the Project
Trial	Pilot Project	E-trucks	2016	• No. of e-trucks planned:15 • Battery capacity range: 200–300 kWh • Driving range: 140–200 km • Energy consumption range: 1–1.5 kWh/km • Charging mode: Combination of overnight charging and opportunity charging
Germany (Murray Slovick, 2019)	Trial	E-trucks	2016	• Electric truck highway of 10 km length tested on public road • The highway allows trucks to connect to electrified lines with an overhead equipment while travelling at speed of 90 kmph • Power is directly transmitted to the vehicles with an optimal efficiency of 80% • Expecting a sharp reduction in CO_2 and nitrogen-oxide emissions • Fuel savings worth of $ 22,000 over 1 lakh km
UK (DAF Trucks, 2021)	Trial	E-trucks	2021 (to commence)	• Department for Transport (DfT), UK took efforts to encourage the adoptions of EVs in commercial transport • No of e-trucks planned: 20, 19-tonne rigid type • Battery capacity: 282 kWh (252 kWh effective capacity)

				• Driving range: 280 km • Preferable charging mode: overnight charging; batteries can be charged using AC charger from 20% to 80% in 6.5 hours and from 0% to 100% in 12 hours • Using a DC fast charger (150 kW), 20% to 80% in 1 hour and 0% to 80% in 2 hours
London (Mayor of London et at al, 2018)	Trial	E-LDVs	2017	• Tested feasibility of electric delivery vans for last-mile delivery, which were added to the existing fleet • The project included installation and testing of charging points at the depot. This helped to understand the additional demand on the grid • Electricity cost for charging up the trial vehicles was 75% less than the fuel cost of diesel counterpart
US (West Coast Clean Transit Corridor Initiative, 2020)	Initiative	E-trucks	2020	• The **West Coast Clean Transit Corridor Initiative** aims to install charging sites capable of charging HDTs at 2 MW along key transit corridors from Mexico to the border with Canada by 2030.

Annexure 2: Well-to-Wheel Emission Analysis

The analysis considered the overall CO_2 emissions of the fuel/energy right from the point of source (well) to its point of utilisation (wheels) (Srikkanth Ramachandran & Ulrich Stimming, 2015). Thereby, the Well-to-Wheel (WTW) analysis is divided into two parts, Well-to-Tank (WTT) and Tank-to-Wheel (TTW), as shown in Figure 12. WTT represents the upstream emissions, comprising emissions associated with production of fuel from the refineries (in the case of ICE vehicles) or electricity generation (in the case of EVs). Whereas, TTW represents the tailpipe emissions, comprising emissions associated with vehicle operation using fuel in the tank.

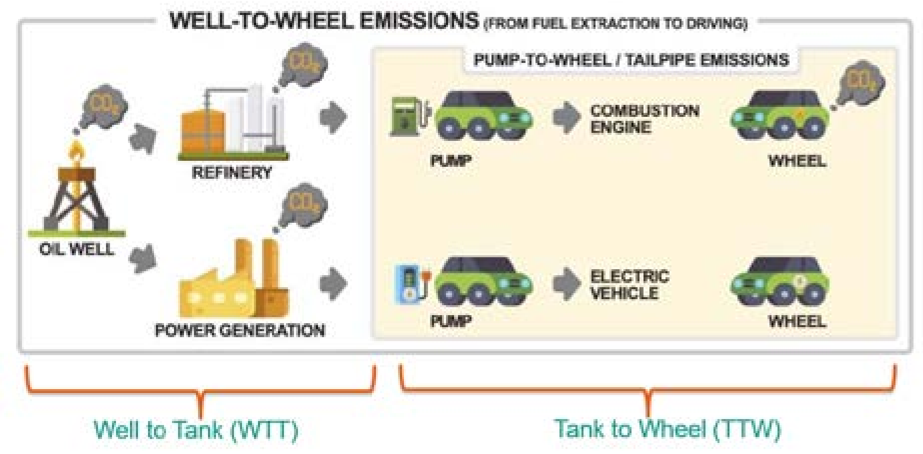

Figure 12: Schematic of well to wheel analysis (Source: Louisiana Clean Fuels, 2021)

Methodology: CO_2 Emission Savings

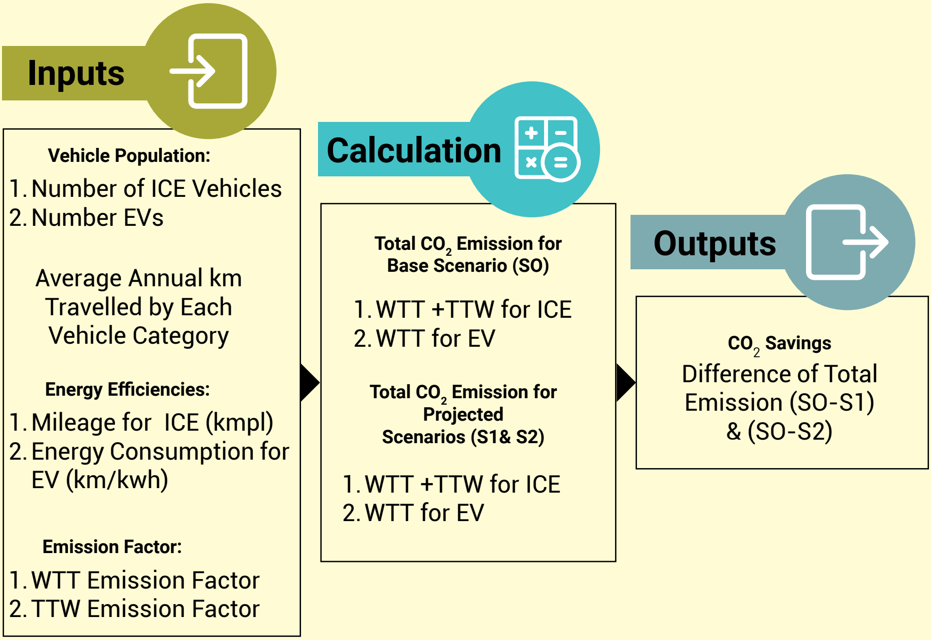

Figure 13: Methodology for estimating CO_2 emission savings
(Source: Author's analysis)

To calculate WTW emissions, the inputs required are—vehicle population of each engine category, average annual km-travelled, energy efficiencies, and emission factors. CO_2 emissions are calculated separately for ICE and EVs and added together to get the total emissions for each scenario. Difference in emissions between the base scenario and the developed scenarios (slow or fast electrification) would be the emission savings for each case. The emissions are calculated as follows:

Total CO_2 emissions for ICE vehicles =

$$\frac{\text{Vehicle population } \times \text{ total annual km travelled (km)} \times \text{ emission factor}(\text{kg}\frac{\text{CO2}}{\text{lit}})_{WTT}}{Fuel\ efficiency\ (kmpl)} + \frac{\text{Vehicle population } \times \text{ total annual km travelled (km)} \times \text{ emission factor}(\text{kg}\frac{\text{CO2}}{\text{lit}})_{TTW}}{Fuel\ efficiency\ (kmpl)}$$

Total CO_2 emissions for EV =

$$\frac{\text{Vehicle population } \times \text{ total annual km travelled (km)} \times \text{ emission factor}(\text{t}\frac{\text{CO2}}{\text{mWh}})_{WTT}}{Energy\ consumption\ (km/kWh)}$$

Inputs/Assumptions

The inputs and assumptions for the emission factors considered in the estimation are given in the tables below.

Mode	Average km-run per year (km)	ICE vehicles	Electric vehicles
		Mileage (km/lit)	Energy consumption (kWh/km)
2W	12,000	50	0.03
3W	54,700	20	0.07
4W	11,000	10	0.14
Bus	43,800	4	1.25
LGV	30,000	10	0.15
MGV	37,000	3	0.8
HGV	60,000	4	1.2

Table 1: Mode-wise input values considered

Sources: The average km-run per year was taken from (Goel & Guttikonda, 2015; Malik & Tiwari, 2017; Salil Arora et al., 2011); the mileage of ICE vehicles was used from market surveys and K.S. Nesamani, 2015; Rahul Goel et al., 2013; the energy consumption of EVs was collated from market surveys and Liimatainen et al., 2019.

Mode	ICE vehicles		Electric vehicles	
	WTT ($kg\ CO_2$ / lit)	TTW ($kg\ CO_2$ / lit)	Grid emission factor ($t\ CO_2$ /MWh)	Coal mix (%)
2W	0.61	1.99	0.511	54%
3W	0.61	1.99		
4W	0.61	2.51		
Bus	0.78	2.51		
LGV	0.78	2.51		
MGV	0.78	2.51		
HGV	0.78	2.51		

Table 2: Mode-wise emission factors

Sources: WWT and TTW emission factors for diesel were taken from Georg Bieker, 2021; Sunitha Anup & Ashok Deo, 2021; the projected coal mix and the projected grid emission factor for 2030 was taken from Central Electricity Authority, Government of India, 2020.

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