What is the Electrification Potential of Door-to-door Waste Collection Vehicles in India?

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Foreword

Shri Gulpreet Singh Aulakh, IAS
Commissioner, Municipal Corporation of Amritsar

Over the last decade, India has seen rapid growth in electric vehicle adoption, backed by national and state government support. Amritsar has actively participated in this shift towards sustainability, notably through the Rejuvenation of Auto-Rickshaws in Amritsar (RAAHI) scheme, which facilitated the replacement of diesel passenger autos with electric ones. This transition is crucial for lessening the harmful environmental impacts, particularly air pollution, and lowering transportation expenses.

While many fleet segments have started witnessing high penetration rates of electric vehicles, waste collection vehicles have received less focus. This study comes at a crucial juncture where Indian cities can now think beyond electrifying mainstream vehicle fleets. Door-to-door waste collection vehicles have a significant potential for electrification, as correctly emphasised in this study. Through this transition, municipal bodies can save emissions, reduce noise pollution and cut fuel expenses. Amritsar, one of the major North Indian cities, witnesses a regular flow of tourists, impacting its economy and municipal services. More than 400 tonnes of municipal waste is generated in the city, which needs efficient and sustainable transportation.

Municipal Corporation of Amritsar aspires to improve the well-being of its citizens by continuously innovating methods which can reduce health burdens such as air pollution. The study's findings regarding the economic benefits of electrification and the suitability of vehicle technology will help us chart a future roadmap for our waste collection fleet. This research also offers valuable insights for other Punjab municipalities and our waste management concessionaire to explore EV adoption. In this manner, we also align with Punjab's EV policy, which emphasises the electrification of waste collection vehicles. Furthermore, the study's national fleet projections can inform automobile manufacturers in developing suitable EV solutions for the waste management sector.

I congratulate the CEEW team on coming up with this timely study for promoting such scientific research to improve the urban environment in cities of Punjab.

Commissioner
Municipal Corporation
Amritsar

About CEEW

The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses **data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources**. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. CEEW is a strategic/ knowledge partner to 11 ministries for India's G20 presidency.

The Council's illustrious Board comprises Mr Jamshyd Godrej (Chairperson), Mr S. Ramadorai, Mr Montek Singh Ahluwalia, Dr Naushad Forbes, Dr Janmejaya Sinha, Dr Suresh Prabhu, and Ms Vinita Bali. The 350+-strong executive team is led by Dr Arunabha Ghosh. CEEW has repeatedly featured among the world's best managed and independent think tanks.

In over 14 years of operations, The Council has engaged in 500+ research projects, published 460+ peer-reviewed books, policy reports and papers, created 220+ databases or improved access to data, advised governments around the world 1400+ times, promoted bilateral and multilateral initiatives on 160+ occasions, and organised 610+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the CEEW Centre for Energy Finance. In August 2020, Powering Livelihoods — a CEEW and Villgro initiative for rural start-ups — was launched by Minister Piyush Goyal, Dr Rajiv Kumar (then NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: Informing India's net-zero goals; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, *Swachh Bharat*; pathbreaking work for India's G20 presidency, the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the first independent evaluation of the *National Solar Mission*; India's first report on global governance, submitted to the National Security Advisor; support to the National Green Hydrogen and Green Steel Missions; the 584-page *National Water Resources Framework Study* for India's 12th Five Year Plan; irrigation reform for Bihar; the birth of the Clean Energy Access Network; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); India's largest multidimensional energy access survey (ACCESS); critical minerals for *Make in India*; India's climate geoengineering governance; analysing energy transition in emerging economies, including Indonesia, South Africa, Sri Lanka, and Viet Nam. CEEW published *Jobs, Growth and Sustainability: A New Social Contract for India's Recovery*, the first economic recovery report by a think tank during the COVID-19 pandemic.

The Council's current initiatives include: State-level modelling for energy and climate policies; consumer-centric smart metering transition and wholesale power market reforms; modelling carbon markets; piloting business models for solar rooftop adoption; fleet electrification and developing low-emission zones across cities; assessing green jobs potential at the state-level, circular economy of solar supply chains and wastewater; assessing carbon pricing mechanisms and India's carbon capture, usage and storage (CCUS) potential; developing a first-of-its-kind Climate Risk Atlas for India; sustainable cooling solutions; developing state-specific dairy sector roadmaps; supporting India's electric vehicle and battery ambitions; and enhancing global action for clean air via a global commission 'Our Common Air'.

The Council has a footprint in over 20 Indian states, working extensively with 15 state governments and grassroots NGOs. Some of these engagements include supporting power sector reforms in Uttar Pradesh, Rajasthan, and Haryana; energy policy in Rajasthan, Jharkhand, and Uttarakhand; driving low-carbon transitions in Bihar, Maharashtra, and Tamil Nadu; promoting sustainable livelihoods in Odisha, Bihar, and Uttar Pradesh; advancing industrial sustainability in Tamil Nadu, Uttar Pradesh, and Gujarat; evaluating community-based natural farming in Andhra Pradesh; and supporting groundwater management, e-auto adoption and examining crop residue burning in Punjab.

The *Swachh Bharat Mission* has been instrumental in providing 100% door-to-door waste collection coverage in Indian cities.

Contents

Indian cities such as Lucknow have already leapfrogged by deploying a full fleet of electric door-to-door waste collection vehicles.

Executive summary

Around 150,000 tonnes of waste is collected daily in Indian cities (CPCB 2021), and its collection and transportation can account for around half of a city's municipal expenditure on waste management (Ahluwalia and Patel 2018). Emissions data for waste collection and transportation is limited. However, one study highlights that municipal waste transportation annually emits around 67 thousand tonnes of CO_2, 613 tonnes of NOx and 100 tonnes of Particulate Matter (PM) in Mumbai (B.K. Sharma and Chandel 2019). Solid waste management (SWM) has become increasingly crucial for air pollution emission reduction strategies, and cities must develop strategies to cut emissions through an economically effective transition. The Council on Energy, Environment and Water (CEEW), as part of its efforts to develop sustainable mobility strategies to reduce air pollution, has analysed the potential of electrifying incumbent internal combustion engine (ICE)-based door-to-door (D2D) waste collection vehicles in Indian cities.

Punjab is the only state in India with an EV policy that aims to electrify waste collection fleets by providing targeted incentives. We have used Amritsar as a case study to showcase D2D waste collection fleet electrification's impact and benefits, as the city has already gained momentum in clean transport through its RAAHI scheme, accelerating the electric transition of its diesel passenger autos. Moreover, Amritsar represents a typical million-plus non-attainment city under the National Clean Air Programme (NCAP). The city's population of around 1.4 million generates 425 tonnes of waste daily. We collected data from city authorities, including trip details of the waste collection vehicle fleet and conducted interviews with drivers, private operators, and several waste management experts. A market review of the available ICE and electric vehicles forms the base for analysis. Using the case of Amritsar, this study highlights the high economic and environmental benefits of EV transition in D2D waste collection operations.

> **Indian state EV policies can mandate or regulate the electrification of municipal fleets.**

Moreover, escalating solid waste generation rates (Kumar and Agrawal 2020) and increasing urbanisation in India drive the concurrent demand for waste collection and transportation. Class I Indian cities (cities above 1 lakh population) generate almost 70 per cent of India's total annual solid waste (K.D. Sharma and Jain 2019). Thus, the D2D waste collection fleet requirements in Class I Indian cities were estimated by analysing waste generation trends and MoHUA's waste collection vehicle deployment standards. Based on the fleet requirements, we created EV transition scenarios till 2030. Finally, the D2D waste collection ecosystem's electrification potential is summarised using a Political, Economic, Social, Technology, Environmental and Legal (PESTEL) framework, which provides a net positive outlook for electrification.

Key findings

The EV transition potential is high due to the D2D waste collection vehicle segment's fixed route operations, scheduled daily trips and adequate fixed parking availability with municipal corporations. Since the primary performance metric for D2D waste collection vehicle operations is the amount of waste transported rather than the distance travelled daily, the total cost of ownership per tonne (TCO/tonne) is a better metric to assess SWM EV potential than TCO/km.

- **Benefits of electrifying D2D waste collection vehicles in million plus cities like Amritsar**

  » We found that **300 kg payload e-carts are the most economical at the current daily vehicle utilisation rates of 15-20 km in Amritsar**. However, as daily vehicle utilisation rates increase until they are 50 km or above, 550 kg payload L5N category electric three-wheelers become more economical.

  » Despite the high initial investment, **the TCO for L5N category (three-wheeler) EVs was found to be 20-25 per cent less than that for ICE vehicles used in the segment**. N1 category (four-wheeler) EVs have the highest TCO among all vehicle types due to high upfront costs.

» **In comparison to operating a diesel vehicle fleet, EVs can reduce fuel cost burden by 60-80 per cent** for the Amritsar municipal corporation's D2D waste collection.

» **Three-wheeler EVs will emit 64 per cent less CO2 compared to their existing ICE counterparts during their service life, even after considering coal powered grid level emissions**. Moreover, switching to EVs can avoid 83 kg of PM2.5 and about 0.5 tons of NOx per vehicle can be avoided annually.

- **National-level demand and benefits of D2D waste collection vehicles**

  » Class-I cities (above 1 lakh population) in India will require about 80,000 new D2D waste collection vehicles by the year 2030.

  » India could achieve 65 per cent EV penetration in its D2D waste collection vehicle fleet by 2030 under a High Ambitious Scenario (HAS), assuming that the government mandates exclusive EV procurement in the segment starting in 2027.

  » Electrifying the vehicle fleet under HAS can cumulatively reduce CO2, NOx and PM2.5 emissions from D2D waste collection vehicles by 40 per cent, 34 per cent and 63 per cent, respectively, between 2027 and 2030.

Key recommendations

- **Improving awareness by pilot demonstrations at the city level**

  Limited knowledge of vehicle durability, EV range and charging, wet waste leachate-related concerns, etc., hinder EV adoption in the D2D waste collection vehicle segment. Pilot demonstrations can help resolve these issues resulting in better vehicle design, improved technical capacity, and a faster learning curve in EV operations for city officials. Documenting such pilots can also help other cities in devising their transition strategies.

- **Reducing upfront cost through incentives**

  State EV policy incentives can alleviate higher initial costs or financial constraints. Also, to accelerate this electrification, aggregated demand from urban local bodies (ULBs) can be beneficial in negotiating costs, design specifications, and procurements from original equipment manufacturers (OEMs). States like Punjab have planned to use a 'Swachh Bharat Kosh' for such EV transition, which can be replicated in other states.

- **Developing a targeted transition plan**

  Age distribution, fuel type, and vehicle performance analysis at fleet and city levels can help develop a phased fleet renewal and augmentation plan. The phase-wise integration of electric vehicles must align with the city's current fleet strength, future waste generation trends, and state/national electrification targets. The transition plan must include pilot programmes, capacity building components for officials and drivers, procurement strategies, and plans for charging infrastructure development.

- **Creating demand through national programmes**

  To incentivise EV transition in this segment, the *National Swachh Sarvekshan* of the Ministry of Housing and Urban Affairs (MoHUA), can be modified to integrate EV fleet share as one of the performance metrics for ranking cities. Other ministries, such as the Ministry of Heavy Industries (MHI) and the Ministry of Road Transport and Highways (MoRTH), can nudge the industry to develop standardised, well-designed, suitable vehicles for India's typical waste management operations.

1. Background

With rapid urbanisation, economic growth and the subsequent changes in consumption patterns, Indian cities are burdened with solid waste management (SWM) issues. Recent estimates show India generates 62 million tonnes of municipal solid waste (MSW) annually, with a collection efficiency of 70-90 per cent (Tewari 2021; Singh, Singh, and Singh 2024). At the city level, waste generation varies according to population density, geography, demography, or even the type of local economy. For instance, tourism economy based cities like Leh and Panaji produce almost three times more waste per capita (1–1.2 kg per day per person) than other Indian cities, generating about 0.1-0.5 kg per day per person (Meena et al. 2023; NITI Aayog 2021).

The transport demand to manage this waste in most cities of India is fulfilled by ICE-based vehicles. These vehicles, typically powered by Diesel or CNG, are a source of greenhouse gases (GHG) and air pollutants. According to a study in Mumbai, due to the transportation of MSW through diesel vehicles, around 67,000 tonnes of CO_2, 613 tonnes of NO_x and 100 tonnes of PM are emitted annually (B.K. Sharma and Chandel 2019). Since transportation is an emission-intensive process, there is a need to manage the emissions.

With the onset of the *Swachh Bharat Mission* in India, cleanliness has been a priority at all tiers of governance, and one of the main objectives of the mission was achieving 100 per cent D2D waste collection. Solid waste management in a city consists of three steps: waste collection, waste transportation, and waste treatment (or disposal). The initial stage of waste collection, i.e., the D2D or primary waste collection from household/commercial areas to waste transfer stations, is carried out using light commercial vehicles such as three-wheeler autos/tempos or four-wheeler utility vehicles. The secondary waste collection stage includes the transportation of waste from transfer stations to landfills or dump sites, which is usually done using heavy-duty vehicles such as trucks, dumpers, etc.

Urban local bodies (ULBs) spend 15–25 per cent of their annual revenue expenditure on waste management budget, out of which 45 to 90 per cent is spent on waste collection and transportation (depending on city size) (Ahluwalia and Patel 2018). There is scope for vehicle technology transition in this transportation process and simultaneously reducing related costs.

Indian cities typically deploy ICE-based light commercial vehicles with a payload capacity of 300–1000 kg for door-to-door waste collection.

1.1 Can EVs replace ICE-based door-to-door (D2D) waste collection vehicles?

To reduce tailpipe emissions and gain economic benefits, transitioning the D2D waste collection vehicles to cleaner fuel technologies can have high potential. Due to the fixed scale of operations involved in D2D waste collection, the potential for adopting electric vehicles remains high. India has already indicated and established its ambitions for transitioning to electric vehicles (EVs) through several national and state-level policies. The *Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India* (FAME India) scheme was launched by the Government of India to promote EV adoption at a large scale. Almost all Indian states have also lined up their EV policies to support this technology transition. Financing electric vehicles for smoother adoption has also worked as a lever. However, different fleet segments have varying electrification potential.

A few Indian cities have already started using EVs for D2D waste collection purposes. For instance, **Vijayawada** in Andhra Pradesh piloted an electric three-wheeler-based waste collection system in 2017 (The New Indian Express 2017). The **Andhra Pradesh government procured 1,800 electric vehicles** for waste collection in various cities (The News Minute 2021). **Coimbatore** planned a fleet of 250-plus EVs in 2019 (The Hindu 2019). The **Surat Municipal Corporation** added EVs to its current D2D waste collection vehicle fleet, replacing seventy-nine old ICE vehicles with 124 electric three-wheelers (Times of India 2022). **Lucknow** has also recently deployed more than 700 vehicles in its D2D waste collection fleet (Bitra 2024). **Chennai** has transitioned to a mass operations scale—it manages over 3,000 electric carts (e-carts) for D2D waste collection and serves more than four million people in the city (The Hindu 2020).

Besides Chennai and Lucknow, many other cities have started EV operations in D2D waste collection, underscoring this segment's potential for electric transition. The EV operations are at a pilot scale in most other cities or limited to smaller service areas. Also, most Indian cities use e-carts with a payload capacity between 250 and 400 kg, 50–60 per cent less than ICE vehicles.

This study aims to assess the potential of electrification of D2D waste collection vehicles in India by conducting a feasibility analysis at the city level. Punjab is the only state in India explicitly mentioning its EV transition targets in its 2022 EV policy for waste disposal fleets or D2D waste collection vehicle fleets in its cities. We have selected Punjab's Amritsar city as a case study, as the EV transition there has already gained momentum in the past few years through government schemes such as RAAHI, under which diesel-based passenger three-wheelers have started transitioning to EVs (UITP 2022). We acquired operational characteristics data on these vehicles from city officials to assess the techno-economic feasibility of electrifying Amritsar's D2D waste collection vehicle fleet. We also conducted a comprehensive market review of the existing D2D waste collection vehicle fleet and conducted expert interviews to inform the techno-economic evaluation.

As the MSW generation increases in urban India, there will be a higher demand for D2D waste collection vehicles, and this demand majorly lies in cities with populations above 100,000 people, as more than 70 per cent of India's MSW comes from these cities (Kumar and Agrawal 2020). Thus, there is also a need to assess the future fleet size requirements of D2D waste collection vehicles in Indian cities. Using MoHUA guidelines for deploying D2D waste collection vehicles and waste generation trends in Class-I cities, we have estimated and projected the demand for D2D waste collection vehicles. Lastly, EV transition scenarios for these vehicle fleet segments were created until 2030 to inform the national-level policy interventions. To understand the ecosystem's favourability towards electrification, the analysis is compiled in a Political, Economic, Social, Technological, Environmental and Legal (PESTEL) format, which is already showcased as an effective tool for assessing the potential of electrification (Harikumar et al. 2022).

> **Many Indian cities have already begun testing EVs for door-to-door waste collection.**

BOX 1	Greater Chennai's e-cart based D2D waste collection system

The Greater Chennai Corporation (GCC) uses a fleet of 3,000 e-carts to provide D2D waste collection and transportation services to almost 800,000 households, or around four million people. It serves an area of 207 sq. km., which is 55 per cent (seven out of 15 zones) of the Chennai Metropolitan Region. The service commenced in 2020 with an eight-year contract with a private firm, Urbaser Sumeet. The same fleet is also used for road-sweeping operations.

The fleet works in three shifts:

- Shift 1: Residential waste collection (6:30 a.m. to 1:30 p.m.)
- Shift 2: Commercial waste collection (2 p.m. to 8 p.m.)
- Shift 3: Night sweeping (10 p.m. to 2 a.m.)

The vehicles used for waste collection are fitted with lightweight containers instead of automated tippers, reducing the dead load on the vehicle and making room for more waste. There is no helper for each vehicle, and the residents dump the waste in segregated bins. The software manages vehicles' routes and operational hours, optimises charging and reduces operational costs. All the e-carts are installed with GPS and RFIDs, which ascertain the location, operational hours and work done by the vehicles. The service provider is solely responsible for investing in equipment and manpower. The tipping fee model was discarded, and the payment mode is based on fulfilling key performance indicators. Contract fees are divided 50:50 between fixed pay and variable pay, with variable pay based on performance indicators or service-level benchmarks (Clean India Journal 2022).

The system initially faced several challenges, such as the fact that no driving licence was required for e-carts and no category for them to get registration in the regional transport office (RTO). Thus, it became a grey area. However, a separate e-cart registration category was created after deliberations between GCC and the Transport Department. No registration fee was required, and the Transport Department would collect only a sum of INR 3,500 for the fitness certificate. A driving licence category for e-carts was also added.

The KPI-linked model forces the service provider to perform well and not cut corners. It promotes a decentralised waste management system.

Source: Sait and Salunke 2022; Balasubramanian 2020

1.2 D2D waste collection vehicle market in India

The D2D waste collection vehicles fall under the small/ light commercial vehicles category. All the vehicles in this segment come with a standard chassis that can be used for goods carriage, or modified with tippers for waste collection. As per the Ministry of Road Transport and Highways (MoRTH) classification, D2D waste collection vehicles used in Indian cities broadly fall under three categories: L5N, N1, and/or e-cart.

- The L5N category includes three-wheeler motor vehicles used for carrying goods with gross vehicle weight less than 1,500 kg.

- The N1 category includes four-wheeler motor vehicles carrying goods with a gross vehicle weight of less than 3,500 kg.

- e-carts are three-wheeler battery-operated vehicles for carrying goods. They can reach a maximum speed of up to 25 km/h and have a payload capacity of 300–350 kg.

The size of the solid waste collection vehicles market in India is expected to grow because of the increasing quantity of MSW that needs to be managed daily. Compared to passenger vehicles, the electric vehicle variants in the D2D waste collection (utility segment) are still limited in the Indian market. A few legacy OEMs have launched their electric variants for the D2D collection of the MSW, which are presented in Table 1. The range of the EVs in this segment differs according to the vehicle size and battery. Some OEMs offer swapping technology models in the three-wheeler passenger vehicle segment, but no such technology options are available in the utility or D2D waste collection vehicles. Swapping technology can even reduce the upfront capital cost burden. Still, due to its unavailability for the D2D waste collection use case, the study is restricted to point-charging vehicles only.

Table 1 ICE and EV vehicles available in the D2D waste collection segment in India

	TATA Ace (Diesel/CNG)	TATA Ace Electric	Mahindra Alfa (Diesel/CNG)	Mahindra Treo Zor Electric	Piaggio APE Electric	Viceroy e-cart
MoRTH vehicle category	N1	N1	L5N	L5N	L5N	e-cart
Payload capacity	750 kg	600 kg	400–450 kg	550 kg	506 Kg	300 Kg
Mileage/ Certified range	22 km/l	154 km	30 km/l or 38 km/kg	80 km	90 Km	80–100 km
Gradeability	27.5%	22%	--	7%	17%	--
Battery type	NA	Lithium-ion iron phosphate	NA	Lithium-ion	Lithium-ion	Lead acid
Battery capacity	NA	21.3 kWh	NA	7.37 kWh	8 kWh	--
Charging time	NA	105 mins (Fast) 6–7 hours (Slow)	NA	3 hours 50 mins (slow)	3 hours 45 mins (slow)	--
Battery warranty	NA	5+ years	NA	1 lakh km	1 lakh km	--
Total cost of vehicle (INR)	6–7 lakh (0.6-0.7 million)	8–9 lakh (0.8-0.9 million)	3–3.5 lakh (0.3-0.35 million)	3.5–4 lakh (0.35-4 million)	3.5–4 lakh (0.35-4 million)	2 lakh (0.2 million)

Source: Author's compilation from Original Equipment Manufacturers (OEM) websites (2024)

The choice of vehicles for the MSW collection and transportation is primarily dependent on factors including efficiency (to maximise the coverage in terms of area and amount of waste), convenience (i.e. the vehicles should be easily manageable for both residential and commercial purposes), compatibility (i.e. the vehicles should be compatible with the hydraulics and separator), public health safety (i.e. vehicles with least chances of leakage) and the ownership (i.e. facilities with optimised costs).

Since EV manufacturing for this segment is still evolving, we conducted in-depth discussions with experts from the manufacturing field (EVage), vehicle prototype designers (Advandes Pvt Ltd) and a few municipal SWM managers. We found no existing market estimation of the D2D solid waste collection vehicles for urban India. Industry experts suggest it might range from 60,000 to 90,000. In addition to the legacy OEMs, many start-ups have entered the field and continuously innovated new products through robust research and development. These OEMs also provide ULBs with choices for modifying their current fleet.

Electric vehicles are frequently criticised for their lower endurance in solid waste management systems. From a ULB's viewpoint, the officials are inclined towards pilot programmes at this initial stage of technology development in the D2D waste collection segment. The SWM operational managers in cities have highlighted that leachate from wet waste frequently corrodes the material of vehicles, leading to battery degradation and other logistical shortcomings. However, the OEMs are aware of the leachate problem and are pursuing necessary changes by ensuring that the materials used to make the tipper and body chassis are robust enough to bear such corrosive behaviour.

The daily handling of different waste materials from residential and commercial facilities also impacts the vehicle's longevity. Experts highlight that the average lifespan of a typical D2D waste collection vehicle is seven years. The MoHUA's SWM manual also provides information on the eight-to-ten-year lifespan of waste management vehicles (CPHEEO 2003). In such a case, there is a need for EV manufacturers to learn from past experiences in designing waste collection vehicles, improve the chassis and tippers to serve longer lifespans and safeguard the electrical circuits or powertrain of a typical EV.

Door-to-door waste collection vehicles must have robust hydraulic tippers to empty waste at transfer stations or landfills.

2. Electrification potential of D2D waste collection vehicles in Amritsar

Amritsar currently has a fleet of more than 200 diesel based D2D waste collection vehicles.

The Government of Punjab targets a 100 per cent transition of its existing waste disposal ICE vehicles to EVs by 2027. The Punjab EV Policy 2022 offers purchase incentives for the first 5,000 electric D2D waste collection vehicles across its target municipal corporations (Amritsar, Jalandhar, Ludhiana, Patiala and Bathinda). The policy also highlights the usage of funds under the state's 'Swachh Bharat Kosh' to support this transition. Based on the learnings from Tamil Nadu's capital Chennai, Punjab's Ludhiana city has deployed around 350 e-rickshaws in its waste management system, covering 160 square kilometres of city area (Hindustan Times 2022).

The city of Amritsar has an estimated population of 1.4 million and generates 420 tonnes of daily waste. It is also one of the non-attainment cities in India[1], and vehicular emissions contribute around 30 per cent of the city's particulate matter pollution (MoEFCC 2023). Currently, the city has 200–220 diesel four-wheelers with 750 kg payload capacity available for D2D waste collection. Amritsar's waste collection, processing, and disposal system is contracted to a private agency. The city has three parking locations from where these vehicles are managed daily.

2.1 Cost savings from electrifying D2D waste collection vehicles

To assess the viability of the transition of D2D waste collection vehicles in Amritsar, we determined the total cost of ownership (TCO) of ICE and electric variants. Most D2D waste collection vehicles in Indian cities run on diesel/CNG fuel. The specifications of the different ICE and electric variants mentioned in Table 1 have been used in the TCO analysis. A brief description of the assumptions and calculations is presented in the Annexure.

Information about D2D waste collection, such as daily utilisation (trip lengths), fleet size, operational hours, etc., was collected from Municipal Corporation of Amritsar officials and waste management vehicle operators. A primary component of the analysis was the lifespan of the D2D waste collection vehicles. As discussed with SWM experts and municipal officials, D2D waste collection vehicles usually have seven to eight years of lifespan. Additional costs, such as vehicle purchase, fuel, and taxes, are gathered from market review.

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1. Non-attainment city - The cities which are exceeding the National Ambient Air Quality Standards (NAAQS) for 5 consecutive years are identified as Non-Attainment cities by CPCB

Figure 1 Amritsar's door-to-door waste collection vehicles have three distinct parking depots
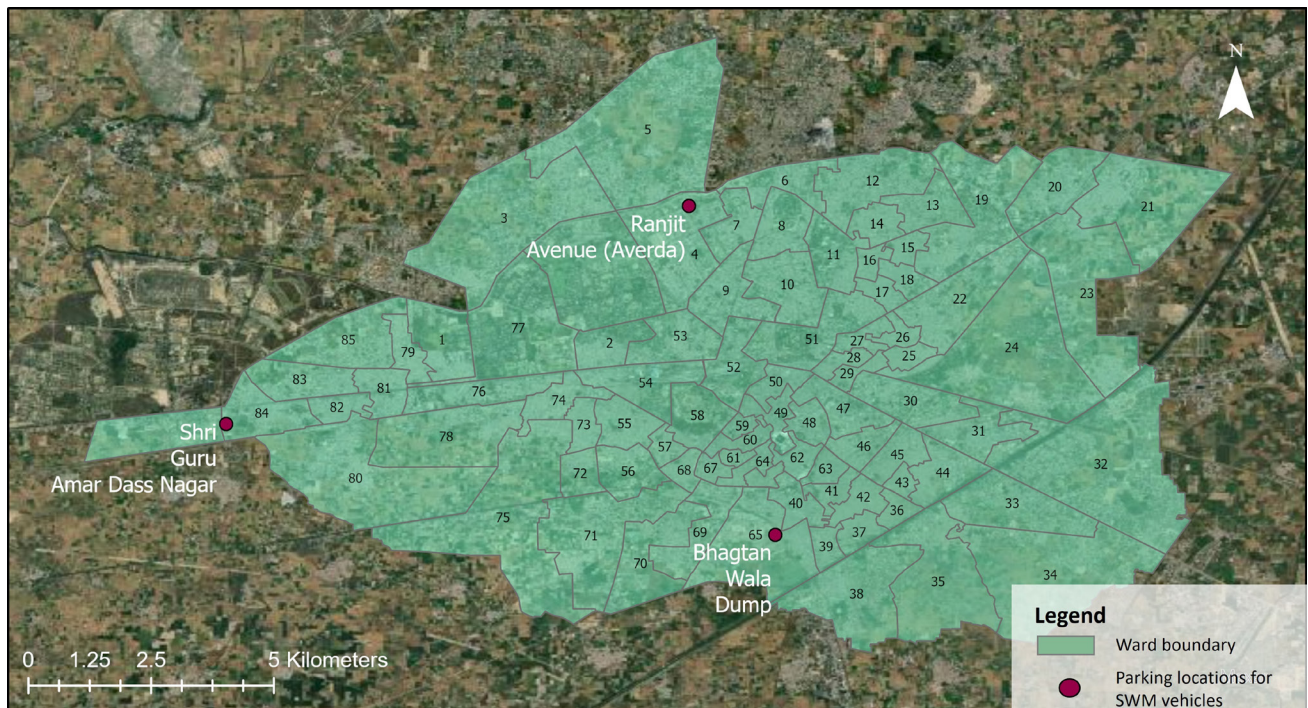
Source: Data obtained from the Municipal Corporation of Amritsar

To have coherence among the ICE vehicles and EVs on fuel efficiencies, the analysis is expressed in terms of kilometres per megajoule (km/MJ). Where an ICE vehicle has a fuel efficiency of 0.4 km/MJ, an EV can give a fuel efficiency of 1.5 km/MJ. Usually, TCO analyses are carried out on a per-kilometre basis (or per-unit distance basis). However, SWM is a specific use case focusing on waste movement across the city, and the payment terms are negotiated on a per-tonne basis. Hence, this study determines economic viability per tonne of waste collected and transported. This will help decision-makers understand the operational parity and provide them with savings per tonne of waste collected.

Figure 2 On a unit distance basis (TCO–INR/km), e-carts are found to be the cheapest to operate in a 15 km daily vehicle utilisation case of Amritsar
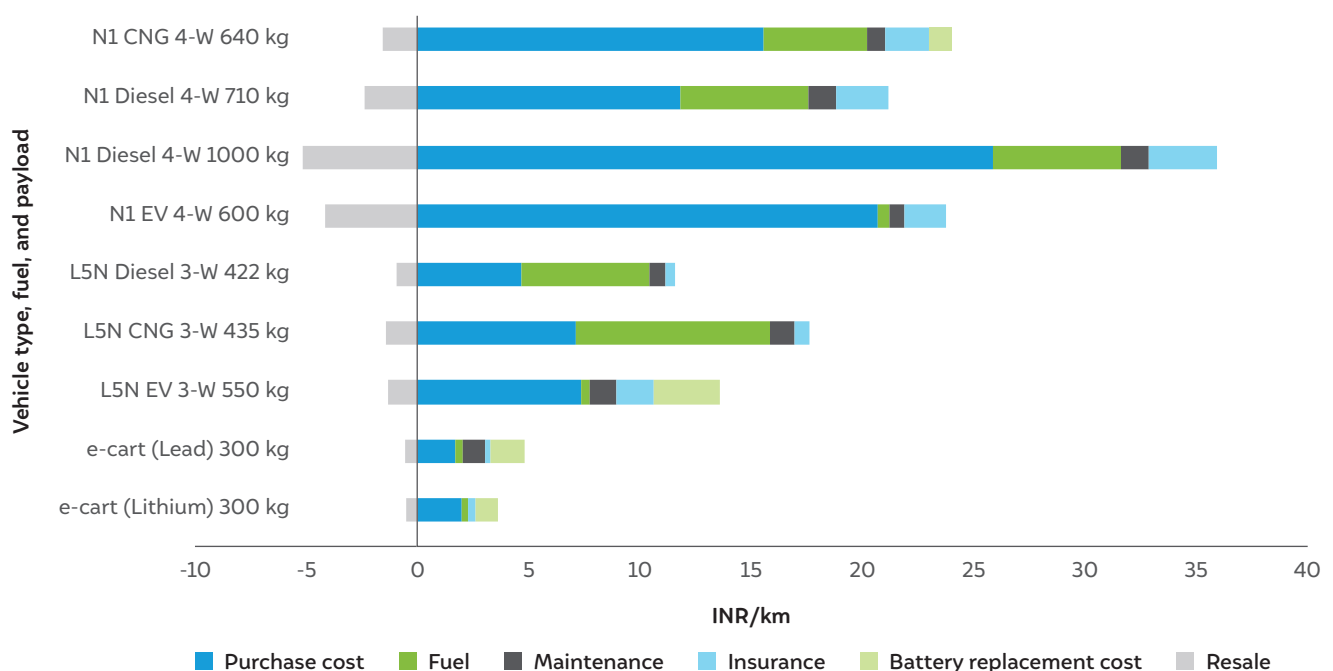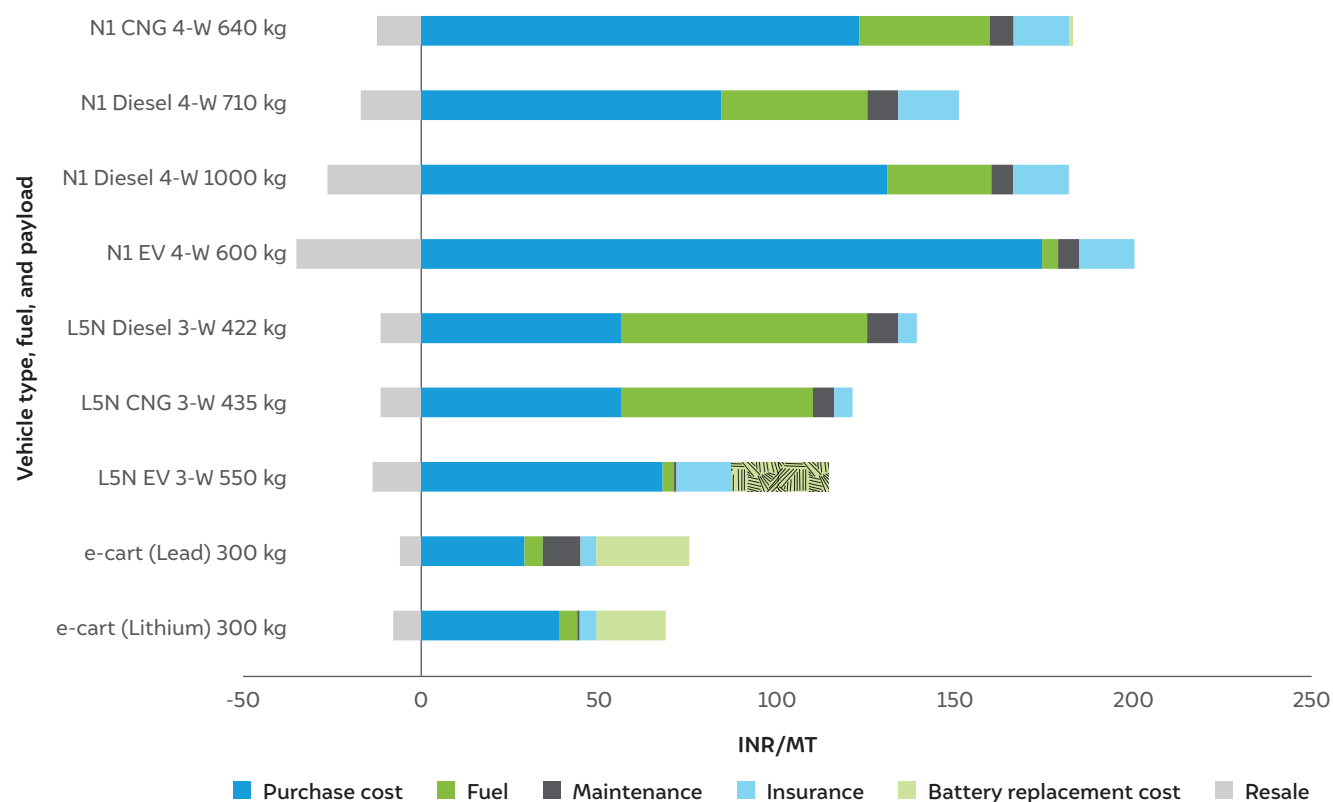

Source: Authors' analysis

At the current D2D waste collection vehicle utilisation of 15 km per vehicle per day in Amritsar, the TCOs (per km) for e-carts are found to be lower than other ICE counterparts. However, as discussed in Section 1.2 and Table 1, ICE vehicles have a higher payload capacity than existing EVs. Thus, the economic benefits of EVs would be misinterpreted if the discussion is restricted to the cost per km conversation only. As per inputs from solid waste managers and sector experts, the concessionaire agreement in most of the cities is at the cost per unit mass of operation (for example, INR/tonne of waste collected). To integrate that aspect, we modified the TCO analysis, and the economic efficiencies of the vehicles on cost-per-tonne of waste collected were evaluated.

The TCO per tonne analysis assumes that each vehicle must carry approximately two tonnes of waste to meet Amritsar's daily demand. Compared to ICE vehicles, TCOs are found to be lowest for three-wheeler EVs and e-carts. Figures 2 and 3 show that the current analysis is based on the 15 km per day utilisation of Amritsar's four-wheeler D2D waste collection vehicles. Different cities have varying daily utilisation rates. Data from

cities of varying population sizes between 100,000 to eight million was collected. In cities such as Bengaluru, Coimbatore, Rajkot, Surat, Jaipur, etc., per day vehicle utilisation of D2D waste collection varies between 10 km to 50 km (Itnal 2015; Velumani 2013; Pujara et al. 2023; Jain et al. 2020; Joshi, Sharma, and Kumar 2021). The overview of other cities suggests that daily D2D waste collection vehicle utilisation is below 55 km. Thus, we also performed a sensitivity analysis of TCOs per tonne till 55 km daily vehicle utilisation.

In Amritsar, the daily vehicle utilisation might also increase depending on the city's ward rearrangements or municipal boundary expansion. Figure 4 shows the change in TCO based on the increasing utilisation of D2D waste collection vehicles. It highlights that the TCOs of ICE vehicles increase rapidly as the daily vehicle utilisation rate increases, whereas the TCOs of L5N category e3W (550 kg payload) and EV 4-W (600 kg payload) rise steadily. e-carts can be considered the cheapest for the city's current vehicle utilisation at 15 km. However, for about 55 km per day utilisation, L5N category e3W (550 kg payload) will be the most economical.

Figure 3 On a per tonne waste collected basis (TCO–INR/MT), e-carts and L5N category e3Ws are found to be the cheapest to operate in a 15 km daily vehicle utilisation case of Amritsar

Source: Authors' analysis

Note: The hatched portion in the chart suggests a battery replacement for three-wheeler EVs, which is conditional only if the vehicle is heavily utilised above the existing levels.

FIgure 4 EV TCO rises more steadily than ICE-based vehicles with higher daily utilisation
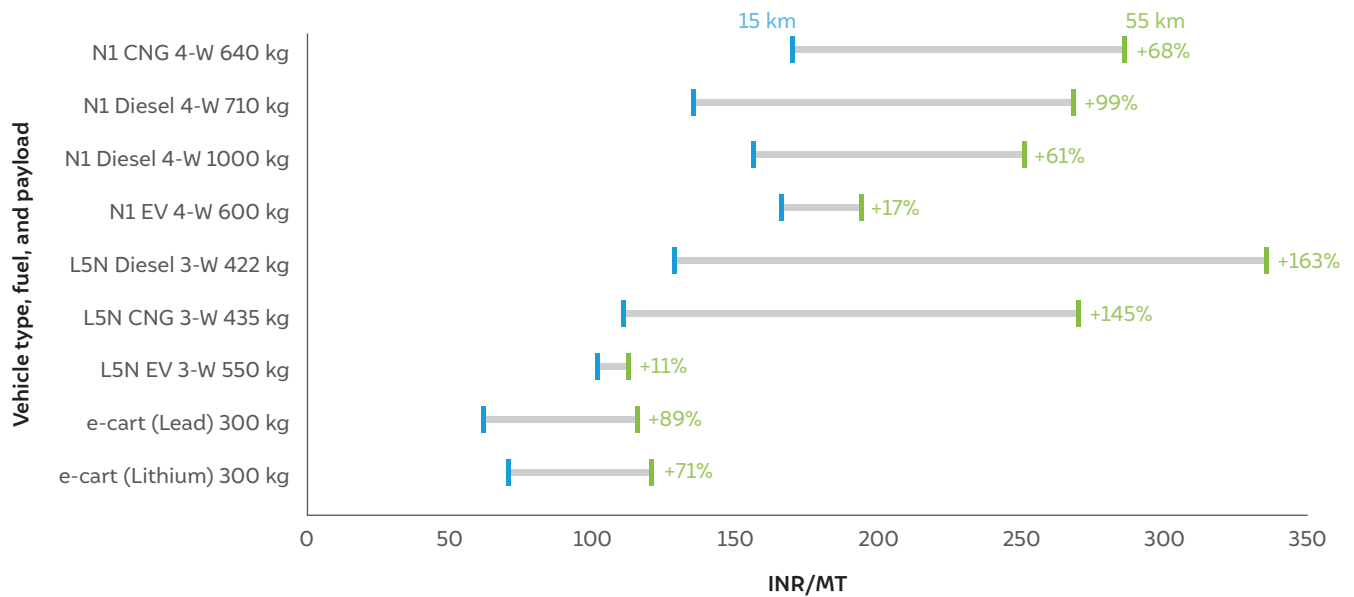
Source: Authors' analysis

Three-wheelers or e-carts have lesser payload capacities than the current diesel four-wheelers in Amritsar. The city's current fleet consists of approximately 200–220 vehicles. To maintain the current level of waste collection service, replacing diesel four-wheelers with EVs of lower payload capacity would necessitate either increasing the daily utilisation per vehicle or expanding the fleet with more EVs. Further analysis indicates that the Municipal Corporation of Amritsar can reduce 60–80 per cent of its fuel costs if it converts its existing D2D waste collection fleet to three-wheeler EVs. For instance, if the fleet of around 200 diesel vehicles is converted to EVs, the MCA can save between INR 5–7 million (50–70 lakh) per year. Additionally, the OEMs manufacturing the EVs guarantee minimum maintenance charges compared to the ICE variants, which can save even more money during operations.

Charging facilities at the municipal workshops/parking facilities would be necessary to support this electric transition. There are eight hours of complete idle time in Amritsar's D2D waste collection operations, which can be effectively used to charge the vehicles. Currently, the MCA has three parking locations spread across the city, which can be used for charging purposes

during non-operational hours. If policies and business models are devised to allow the MCA to publicly offer these charging facilities in lean/non-use periods to generate extra revenue, this also presents an investment opportunity.

2.2 Environmental benefits of electrifying D2D waste collection vehicles

This section focuses on the environmental benefits of the operational emissions, not the embodied emissions (emissions released during the manufacturing of vehicles). We also assumed that all the electricity that the EVs will consume will be primarily produced from conventional sources such as coal. The reduction in emissions may also vary depending on factors such as maintenance, engine load, fuel efficiency, etc. A diesel vehicle emits 1,156 kg of CO_2 annually during its operation in Amritsar, whereas an EV counterpart will produce 64 per cent less CO_2, even considering a coal-powered grid-level emission. As the EVs don't produce any tailpipe emissions, savings of 83 kg of PM2.5 and about 0.5 tons of NOx are estimated annually per vehicle.

BOX 2	Are e-carts a sustainable option in the long term?

An e-cart, which mainly runs on lead-acid chemistry, has a battery that is replaced more often than the lithium-ion-based L5N electric three-wheelers. Traditional e-cart batteries require frequent charging and have shorter lifespans than the lithium-ion batteries found in more advanced electric three-wheelers of the L5N category (Tirpude et al. 2020). Additionally, e-cart manufacturing is highly concentrated in informal markets that lack standardisation, safety, and quality, leading to a shorter vehicle lifespan (Gupta 2021). Thus, e-cart segment requires multiple ecosystem improvements to become a sustainable alternative.

Source: Authors' compilation

3. Fleet requirements for D2D waste collection vehicles at national level

As discussed in Section 1.2, sector experts have highlighted a lack of evidence on the national market size for D2D waste collection vehicles. To calculate and compare the existing and required D2D waste collection fleet, we have used recommendations from the CPHEEO manual 2016 (Table 3). This suggests providing one D2D waste collection vehicle for 1,000–1,500 households, depending on the vehicle's payload capacity to be deployed.

The amount of waste produced at the national level was estimated based on projections of the urban population and per capita waste generation in Class-I cities. As urban populations rise, waste production will increase by 3–4 per cent each year at the city level (K.D. Sharma

and Jain 2019). Based on the existing trend in India's urban population growth, the total waste produced in Class-I cities will reach 216,169 tonnes per day (TPD) by 2030. Further, based on the MoHUA's recommendations for vehicle requirements, the Class-I cities of India will thus require more than 80,000 new vehicles for D2D waste collection by 2030. If planned effectively, electric vehicles have a considerable potential to be part of this future fleet stock.

> **Transitioning from diesel to electric D2D waste collection vehicles could lead to 60-80 per cent of fuel cost savings for cities like Amritsar.**

Table 2 Primary D2D waste collection resource deployment guide

Vehicle for primary waste collection	Number of households to be covered	Total number of people served	Number of staff required
Light Commercial Vehicle (LCV) with 500–700 kg capacity	1,000	5,000	One driver and two labourers per LCV
LCV with more than 700 kg capacity	1,500–2,000	7,500–10,000	One driver and two labourers per LCV

Source: MoHUA 2016

Figure 5 Class I Indian cities will require around 80,000 new D2D waste collection vehicles by 2030
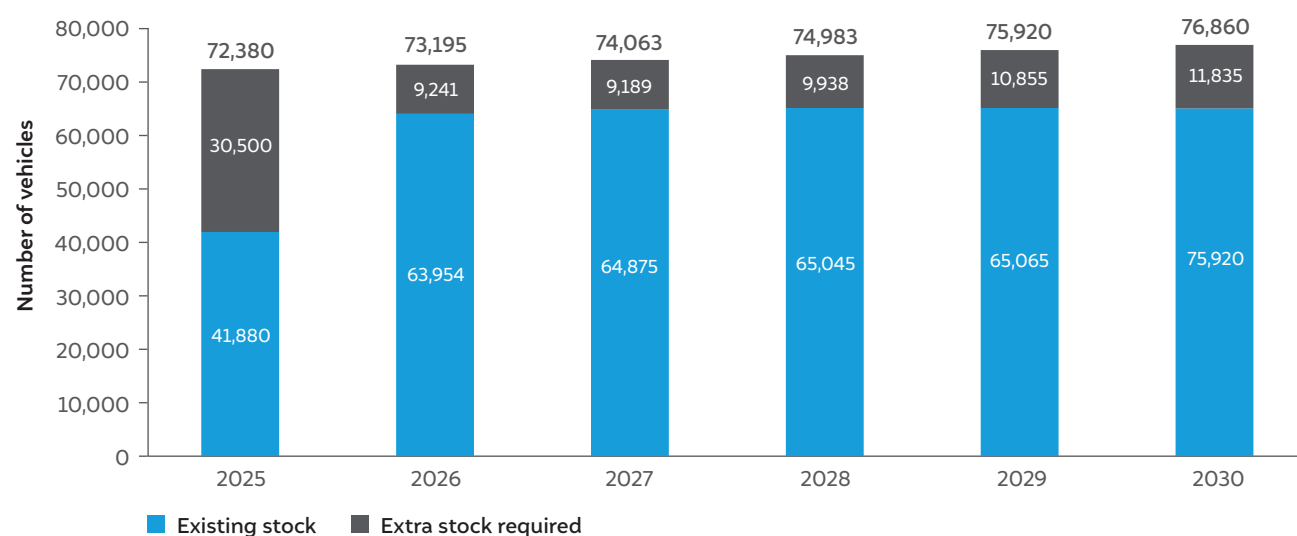
Source: Authors' analysis

3.1 Transition scenarios for D2D waste collection EVs in India

This section recommends two scenarios for procuring new vehicles at the national level. The scenarios are driven by input from sector experts and different sta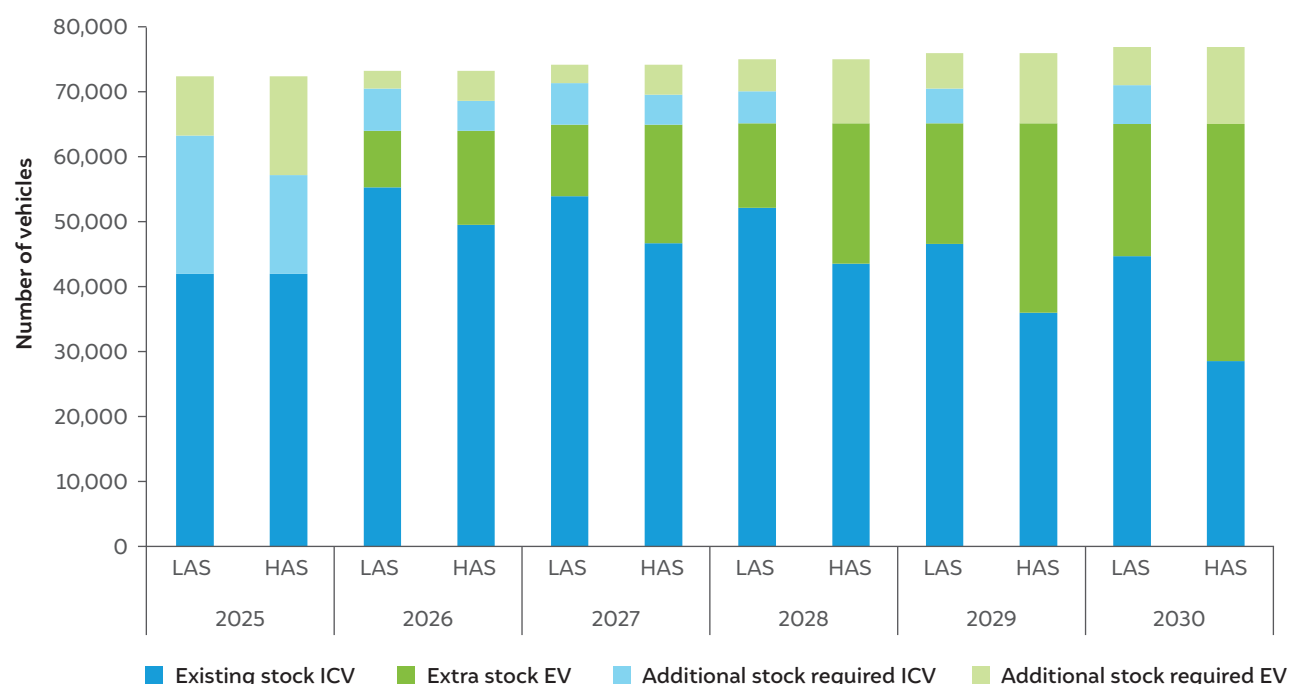te-level EV policy targets in India. The two proposed scenarios are contrasted with a business-as-usual or BAU scenario, in which all future purchases would be diesel-fuelled, and there would be no EV adoption in this fleet category.

Table 3 Electric transition scenarios for D2D waste collection vehicles in India

Scenario	Description and assumptions	EV penetration targets
Business-as-usual	Vehicles deployed in cities at one vehicle per 1,000 households	0% EV penetration
Low-ambition scenario (LAS)	Vehicles deployed in cities at one vehicle per 1,000 households and steady electrification is targeted	2025–27: 30% of new sales are EVs 2028–30: 50% of new sales are EVs
High-ambition scenario (HAS)	Vehicles deployed in cities at one vehicle per 1,000 households, and accelerated electrification is targeted. (The government realises the high potential of electrification in this segment, and the industry response is quick enough)	2025–27: 50% of the new sales are EVs 2027 onwards: 100% of the new sales are EVs

Source: Authors' compilation

Figure 6 Electrification of India's D2D waste collection fleet by 2030 is projected to reach 35% under a Low Ambitious Scenario (LAS) and 65% under a High Ambitious Scenario (HAS)


■ Existing stock ICV ■ Extra stock EV ■ Additional stock required ICV ■ Additional stock required EV

Source: Authors' analysis

In the LAS, a cumulative demand of 26,000 EVs will be generated by 2030, resulting in an EV penetration of about 35 per cent of the total D2D waste collection fleet by 2030. Meanwhile, in the HAS, an EV penetration of about 65 per cent can be achieved through a cumulative demand of around 48,000 EVs in the total D2D waste collection fleet of Indian cities by 2030. We have determined these demands were based on the survival curve, considering the twelve-year life expectancy of these vehicles, and an advancement in vehicle technology was assumed over a period of time.

> **Government policy push will determine the extent of electrification in D2D waste collection vehicles.**

Such electrification scenarios would help reduce greenhouse gas emissions and critical air pollutants from the atmosphere. As the HAS recommends an accelerated adoption rate of EVs, it also results in proportionate benefits in terms of emission reduction. The analysis suggests that the reduction in CO_2 emissions between the base year 2025 and the target year 2030, in the case of LAS and HAS scenarios respectively, will be 22 per cent and 40 per cent. The analysis further projects a 34 per cent to 63 per cent reduction in PM2.5 and NOx emissions by 2030 (in LAS & HAS, respectively) compared to the BAU (2025 baseline). Thus, this would also help the cities improve their environmental health and reduce the exposure burden of the people directly involved in this occupation.

Figure 7 In the high ambitious scenario (HAS), an average of ~25% of CO_2 emissions will be reduced each year between 2025 and 2030

BAU   LAS   HAS
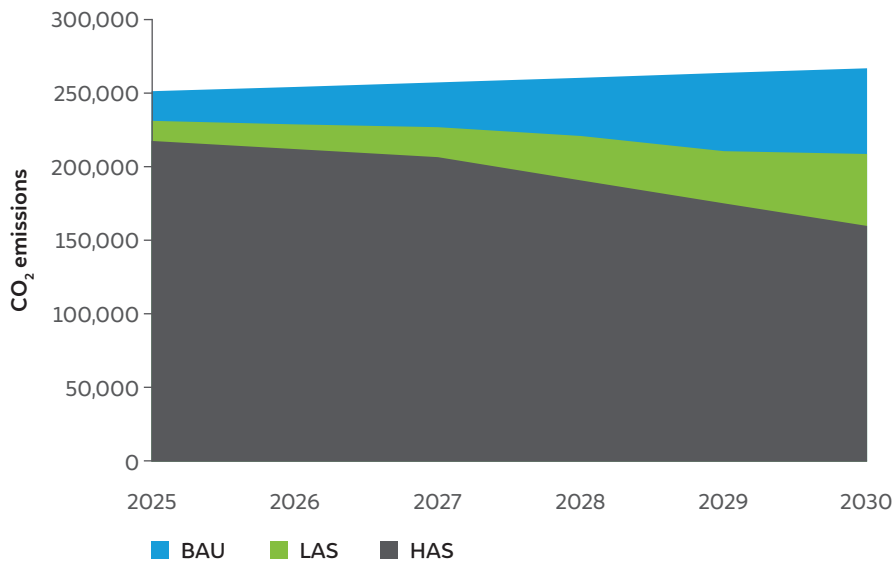
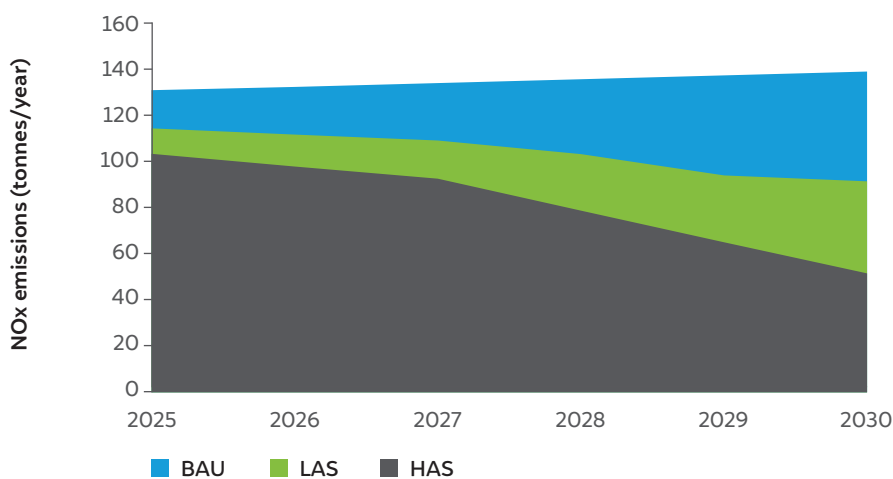*Source: Authors' analysis*

Figure 8 Under the high ambitious scenario (HAS), annual PM2.5 emissions could fall by over 60% in 2030

BAU   LAS   HAS
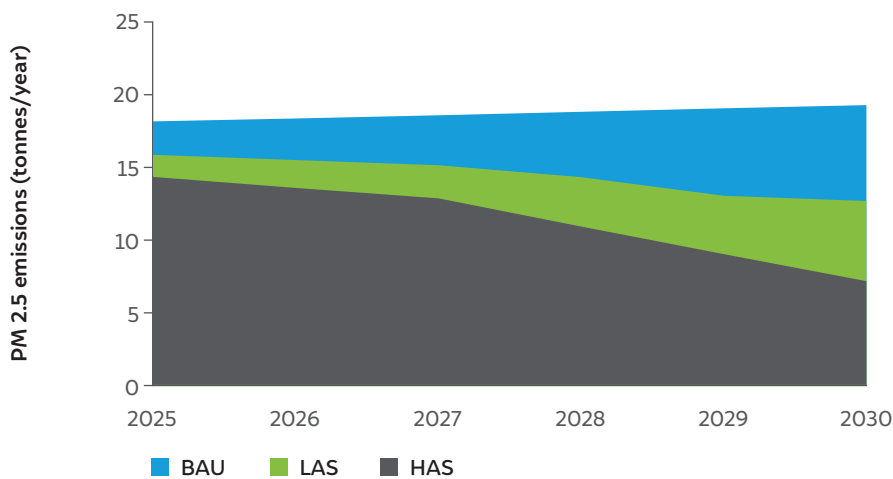
Figure 9 The high ambitious scenario (HAS) also offers the potential for reducing NOx emissions annually by more than 50% by 2030

BAU   LAS   HAS

Source: Authors' analysis

3.2 PESTEL analysis of electrifying D2D waste collection vehicles in India

We have used a PESTEL analysis (Political, Economic, Social, Technological, Environmental, and Legal) framework to assess the electrification potential of D2D waste collection vehicles in India. This has been established as an essential tool for electrification potential assessments (Harikumar et al. 2022). The observations highlighted in Table 4 summarise insights gathered from the analysis, market review, stakeholder interactions and review of government policies.

In addition to findings from Amritsar's case study in section 2, the overall ecosystem presents a net positive outlook, with the benefits outweighing the drawbacks, indicating a significant potential for electrification in this segment. Cities can gain financially by electrifying this particular vehicle category, which can be facilitated through schemes/programmes such as the *Swachh Bharat Mission*, *National Clean Air Programme*, FAME, etc.

Table 4 PESTEL analysis indicates a net positive case for electrifying D2D waste collection vehicles in Indian cities

	Positives	Negatives	
P	• National focus on cleanliness through *Swachh Bharat Mission* • Technology transition supported by government schemes such as *FAME* • Union Budget 2024 emphasised the importance of e-mobility, highlighting the e-transition for government-owned vehicles	• Limited adoption of EVs in this segment till now, and current EV operations are also restricted to small pilots	P
E	• Operations and maintenance costs can be reduced. Hence, ULBs can save on expenses for waste collection • Carbon credit linkages can be established by converting the whole fleet to electric	• High upfront costs of EVs in comparison to the ICE counterparts	E
S	• ULBs can set EV transition examples for private players and society at large • Eco-friendly branding of the essential municipal service can be achieved	N.A.	S
T	• Transition of the government-owned fleet with fixed route-based operations is easy • Clean fuel technology advancements and several start-ups innovating in the sector	• Impact of wet waste on battery and powertrain not yet established • Capacity development required for new technology operations and set-up of charging infrastructure	T
E	• Less GHG emissions and reduced PM, NOx emissions • Less noise pollution	• Dependency on fossil fuels to meet power requirements • Disposal and management of battery waste are still a concern	E
L	• Electrification as local policy action as a part of the National Clean Air Programme (NCAP) • Incentives on vehicle purchases and relaxations on permits and taxes, etc., through state EV policies	N.A.	L

Source: Authors' compilation

4. Recommendations

The TCO analysis presented in this study indicates great economic potential in electrifying the D2D waste collection fleet, and also shows a reduction in the burden of fuel costs for city authorities. To estimate the potential of electrification in typical waste management cases, cities must estimate TCO/tonne instead of TCO/km, as shown in Amritsar analysis. The same method can be used to select the optimal vehicle payload capacity and fuel to reap the maximum financial and environmental benefits in other similar cases of municipal operations. The analysis can be modified to estimate suitability for government vehicle segments such as postal vehicles, delivery vans, water tankers, etc. The national scenarios presented in the study demonstrate a pivotal opportunity to accelerate the EV transition in the D2D waste collection segment. Still, various interventions and innovative approaches will be required at different tiers of governance.

Improving awareness through pilot demonstrations at the city level

This was a key takeaway from the interviews with city officials and private operators. Since EVs are a new-age technology, especially when handling waste, demonstrations and pilots at the municipal level are a must and should be monitored for a certain period. The monitoring will help generate evidence to improve vehicle design and assist other ULBs in electric transition. Think tanks, NGOs, academia, etc., can help in pilot monitoring and evidence-generation stages. Cities like Chennai and Lucknow, which are in an advanced stage of operations, can create knowledge-sharing platforms to assist other cities in understanding the nuances.

A data-based performance matrix must be developed to assess the effectiveness of pilots or demonstrations. Since waste management operations are distributed across municipal areas, high-potential wards/zones can be identified to run these pilots based on charging infrastructure in municipal workshops or parking locations. Such pilots and platforms can help cities identify a vehicle type suitable for D2D waste collection. A feedback mechanism from pilot EV drivers will also aid in informing future deployment decisions.

Incentivising city governments or concessionaires to include EVs in their vehicle fleets

This study's market review showed that EVs' capital costs are comparatively higher than their ICE counterparts. India's FAME/state-level EV policies

Indian cities are at a crucial point for electrifying their door-to-door waste collection vehicles.

provide incentives for three-wheeler and four-wheeler commercial segments. Only the Punjab EV policy provides incentives and a fleet electrification target for waste disposal vehicles. Along similar lines, other states can study the potential of this segment and give incentives to increase the uptake of EVs in D2D waste collection vehicles. These incentives can be provided to ULBs or concessionaires who own the vehicle fleet.

States can formulate EV transition funds focussed on accelerating their penetration in high-potential segments or government-owned vehicle fleets. Purchase incentive mechanisms can be pushed through different government schemes or programmes. For instance, the *National Clean Air Programme's* city action can facilitate this EV transition through their targeted funding mechanisms. Punjab's EV policy mentions using 'Swachh Bharat Kosh', i.e. funds earmarked for cleanliness- related interventions, to incentivise this EV transition.

Developing a technology transition plan at the city level

The ULBs must analyse their current D2D waste collection fleet based on age distribution, fuel type, daily operations, etc., to develop fleet renewal and augmentation plans. These plans can have phase-wise integration of EV procurement in line with set national/ sub-national-level electrification targets. In addition, cities can set their own targets for EV penetration or emission reduction through EV integration. Since individual ULBs will slowly transition to EV technology, aggregate demand from different ULBs would be more effective in reducing costs.

> **States can earmark funding for EV transition in this segment using mechanisms such as Punjab's 'Swachh Bharat Kosh'.**

The EV transition plans must outline the pilot programmes and improve the capacity-building exercises for drivers or operators. After thoroughly analysing the city's existing business model of solid waste management and financing mechanisms, procurement strategies should be included in the transition plans. Cities must analyse their existing land bank and parking locations to strategically plan charging infrastructure for optimum utilisation of the electric D2D waste collection fleet.

Electrifying D2D waste collection vehicles through national policy pushes

As highlighted in this study, D2D waste collection has a high potential for electrification. The projections for Class-I cities show a cumulative demand of around 80,000 new vehicles by 2030. Central-level government organisations such as the MHI, MoRTH, MoHUA, etc., can push for D2D waste collection fleet transition in their electrification programmes.

Electric vehicles can also be included in MoHUA's National SBM guidelines as a vehicle alternative. This ministry's annual Swachh Sarvekshan ranks cities based on their waste management performance. It can reward city governments or municipal bodies that transition a specific proportion of their ICE-based D2D waste collection vehicles to EVs yearly. The Swacch Sarvekshan rankings or city scoring mechanisms can include EV penetration parameters for D2D waste collection fleets.

Acronyms

D2D	door-to-door		**MoHUA**	Ministry of Housing and Urban Affairs
EV	electric vehicle		**MSW**	municipal solid waste
FAME	*Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles*		**OEM**	original equipment manufacturer
GoI	Government of India		**PESTEL**	Political, Economic, Social, Technological, Environmental, Legal
GHG	greenhouse gas		**SWM**	solid waste management
HAS	high-ambition scenario		**TCO**	total cost of ownership
ICE	internal combustion engine		**ULB**	urban local body
LAS	low-ambition scenario			

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Annexure

Table A1 Rates and expenses associated with different fuel type vehicles in D2D waste collection, considered for TCO analysis

Fuel type	Vehicle model considered	Purchase cost	Payload capacity (kg)	Maintenance (INR/km)	Insurance	Resale
Electric (4W)	Tata ace electric	9,00,000	600	1.00	16,500	1,80,000
Electric (3W)	Treo Zor	3,50,000	550	0.11	6,200	70,000
E Cart (3W)	e-cart	1,50,000	300	0.90	5,000	30,000
CNG (4W)	Ashok Leyland Dost	7,99,000	1,208	1.22	19,000	79,900
CNG (4W)	Tata ACE CNG	6,35,000	640	1.22	18,000	63,500
Diesel (4W)	Tata Intra	6,76,000	1,000	1.43	19,000	1,35,200
CNG (3W)	Mahindra Alfa	2,90,000	435	0.73	5,500	58,000
Diesel (3W)	Mahindra Alfa	2,90,000	422	0.73	5,500	58,000
Diesel (4W)	Tata ACE HT	4,35,000	710	1.22	18,000	87,000

Source: Authors' compilation based on 2023-24 market review from OEM websites

Electrifying door-to-door waste collection is a ready opportunity; targeted policies can drive full conversion within the next decade.

Image: iStock

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