An initiative supported by

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Alliance for an Energy Efficient Economy

CHARGING INDIA'S TWO- AND THREE-WHEELER TRANSPORT

A Guide for Planning Charging Infrastructure for Two- and Three-Wheeler Fleets in Indian Cities

EXECUTIVE SUMMARY

Shyamasis Das, Chandana Sasidharan, Anirudh Ray

September 2020

Executive Summary: Charging India's Two- and Three-Wheeler Transport - A Guide for Planning Charging Infrastructure for Two- and Three-Wheeler Fleets in Indian Cities

Suggested citation:

Das, S., Sasidharan, C., Ray, A. (2020). Executive Summary: Charging India's Two- and Three-Wheeler Transport - A Guide for Planning Charging Infrastructure for Two- and Three-Wheeler Fleets in Indian Cities. New Delhi: Alliance for an Energy Efficient Economy.

About Alliance for an Energy Efficient Economy:

Alliance for an Energy Efficient Economy (AEEE) is a policy advocacy and energy efficiency market enabler with a not-for-profit motive.

About Shakti Sustainable Energy Foundation:

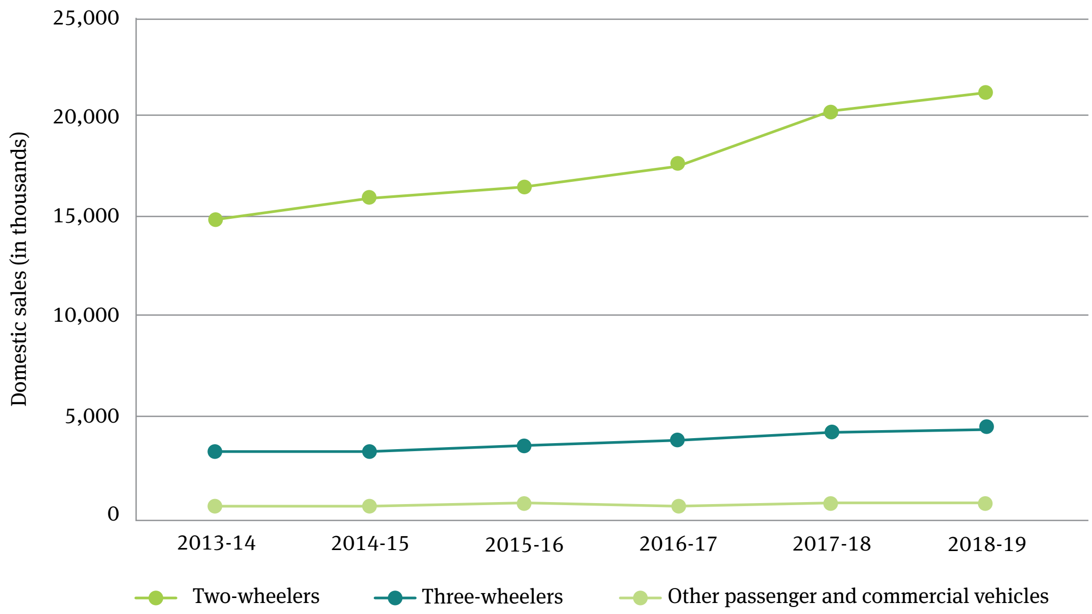
Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

Contact:

Shyamasis Das
Principal Research Associate – Power Utility & Electric Mobility
Alliance for an Energy Efficient Economy (AEEE)
New Delhi
E: shyamasis@aeee.in

Two- and Three-Wheelers, an Important Constituent of India's Road Transport

Two- and three-wheelers form a unique identity of India's motorised road transport. It has been estimated that, together, two-wheelers and three-wheelers constitute about 83%[1] of all vehicles in India. Two-wheelers, constituting the largest share of vehicles in India, are the preferred mode of personal transport in both rural and urban areas. With the rise of e-commerce and delivery services, they have also gained popularity for commercial use in cities. Recent domestic auto sales trend clearly indicates that two-wheelers maintain their dominance in the vehicular mix in the country (Figure ES 1).



ES 1: DOMESTIC AUTOMOBILE SALES TRENDS

Source: Society of Indian Automobile Manufacturers (SIAM, 2019)

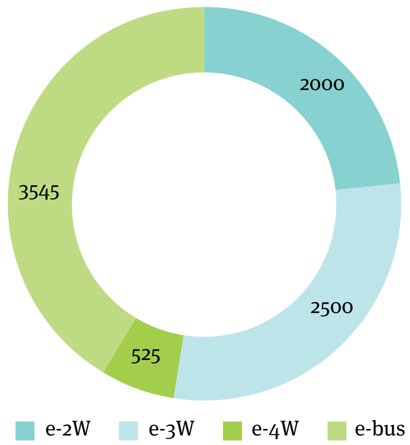
On the other hand, three-wheelers serve as commercial vehicles for passenger and goods transport. They cater to the mobility needs of those not using private transport and not being served by the existing mass transit system. Three-wheelers are also popular for goods transport for short distances. The recent sales figures show that the share of these vehicles is increasing (Figure ES 1).

Electrification of Two- and Three-wheelers – An Absolute Target to Achieve Clean Mobility in India

Electrification of two- and three-wheelers is recognised as a low hanging fruit for clean mobility in India, based on the market readiness, cost-competitiveness, ease of charging, and emission reduction potential. Considering the electric vehicle (EV) penetration potential in these segments, the second edition of the Faster Adoption and Manufacturing of (Hybrid

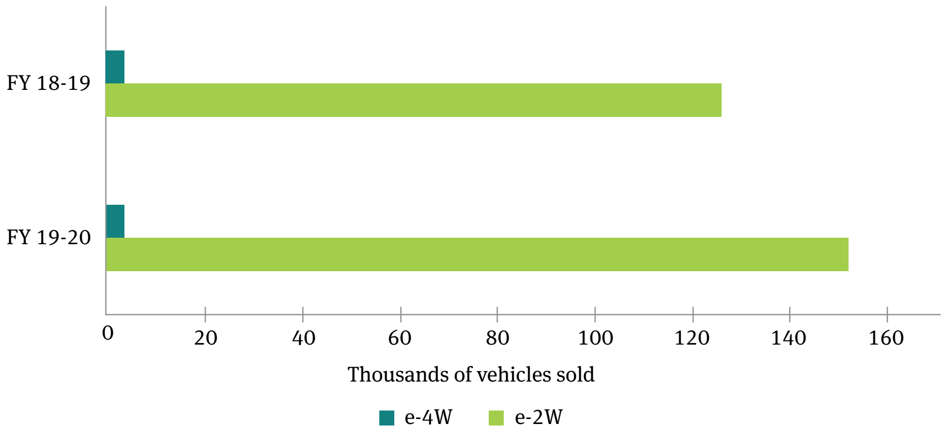
1 Of all the vehicles on Indian roads, 79% are two-wheelers and 4% are three-wheelers (passenger and goods), based on sales data.

and) Electric Vehicles (FAME) scheme includes significant budgetary allocation for demand incentives for electric two-wheelers (e-2Ws) and electric three-wheelers (e-3Ws), as illustrated in Figure ES 2.



ES 2: SHARE OF FUNDS (₹ CRORES) ALLOCATED FOR DEMAND INCENTIVES FOR DIFFERENT EV SEGMENTS UNDER FAME SCHEME

The EV sales trend (ES 3) in the past couple of years shows that the pace of e-2W adoption is much higher than that of electric four-wheelers (e-4Ws), even after accounting for the fact that annual two-wheeler sales have been almost 6-7 times those of four-wheelers in recent years[2]. Though the corresponding sales figures for e-3Ws are not documented, the estimated sales of e-rickshaws were around 90,000 units in fiscal year (FY) 19-20. The growing adoption of e-2Ws and e-3Ws is expected to continue with the right policy elements focusing on the upfront cost reduction. For example, NITI Aayog mooted a proposal to ban sales of internal combustion engine (ICE) powered two-wheelers and three-wheelers starting from 2025 and 2023, respectively. According to NITI Aayog estimates, 80% EV sales penetration is achievable in the two-wheeler and three-wheeler segments by 2030.



ES 3: COMPARISON OF ELECTRIC TWO-WHEELER AND ELECTRIC FOUR-WHEELER SALES

Source: Society of Manufacturers of Electric Vehicles (SMEV, 2020)

It is evident that e-2Ws and e-3Ws are going to play a central role in achieving “shared, connected, and electric” mobility in India. To support the rapid pace of commercial adoption of e-2Ws and e-3Ws, availability of public charging infrastructure will be a crucial factor. Achieving on-ground implementation warrants comprehensive planning which should take into account the following key questions:

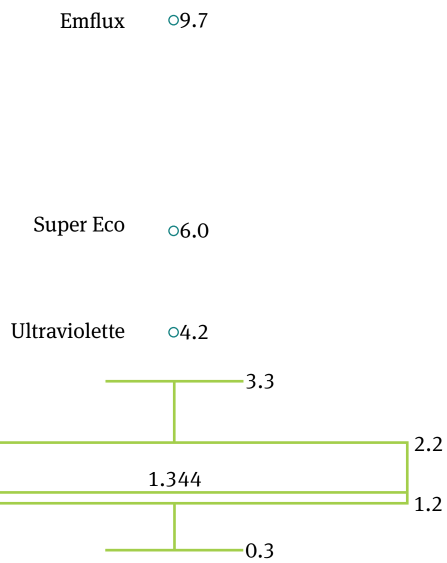
- What are the different segments of two-wheeler and three-wheeler commercial fleets, from the perspective of assessing the charging requirements of electric variants?

2 In FY 19-20, a total of 174 lakh two-wheelers and 6.3 lakh three-wheelers were sold domestically (SIAM, 2020).

- What are the possible ways to charge e-2W and e-3W batteries, and how are they currently being charged? Are there any standards for e-2W and e-3W charging?
- What are the important design aspects of e-2Ws and e-3Ws that impact their charging?
- What are the infrastructural requirements for setting up a charging or swapping facility?
- Is battery swapping a practical alternative to normal e-2W and e-3W charging?
- Going forward, what kind of public charging infrastructure will be required for commercial light electric vehicles in Indian cities?

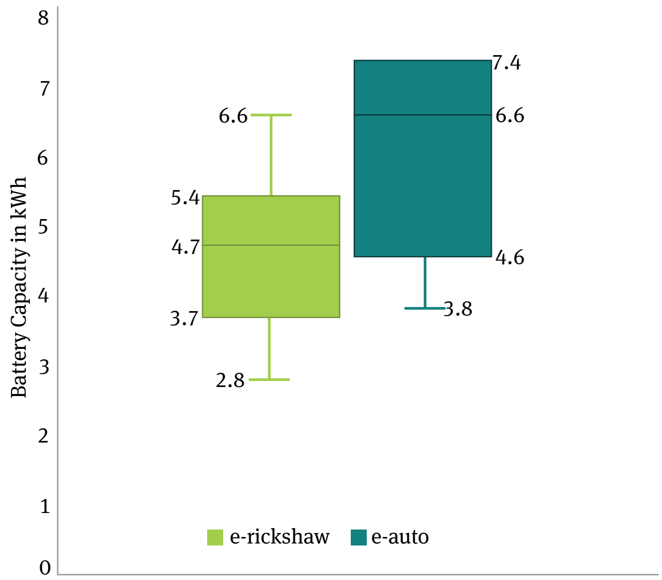
Varied Characteristics of e-2W and e-3W Market

As of 25th June 2020, there are approximately 72 e-2W models[3] with lithium-ion batteries, manufactured by 23 different automakers in the Indian market. On the other hand, there are currently more than 30 e-3W models with lithium-ion batteries. Battery capacity, a key factor influencing the charging requirement of a vehicle, is found to largely vary between 1.2 and 2.2 kilowatt-hours (kWh) in case of e-2W models in India (Figure ES 4). In case of e-3W models, the battery capacity is not the same for passenger and goods vehicles. In the case of e-3Ws, battery capacity is determined by the vehicle application as shown in Figure ES 5 and Figure ES 6.

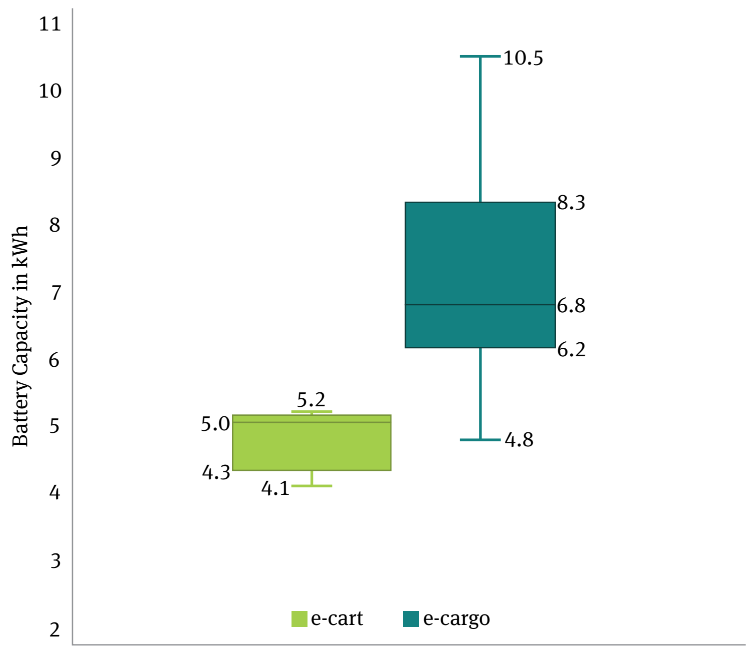


ES 4: BOX PLOT OF BATTERY SIZES (KWH) IN E-2W MODELS WITH LITHIUM-ION BATTERIES

3 Source: AEEE internal analysis. Out of these models, only 19 e-2W models with lithium-ion batteries are eligible for demand incentives under FAME II (Department of Heavy Industry, 2020).



ES 5: BOX PLOT OF PASSENGER TRANSPORT E-3W BATTERY CAPACITY



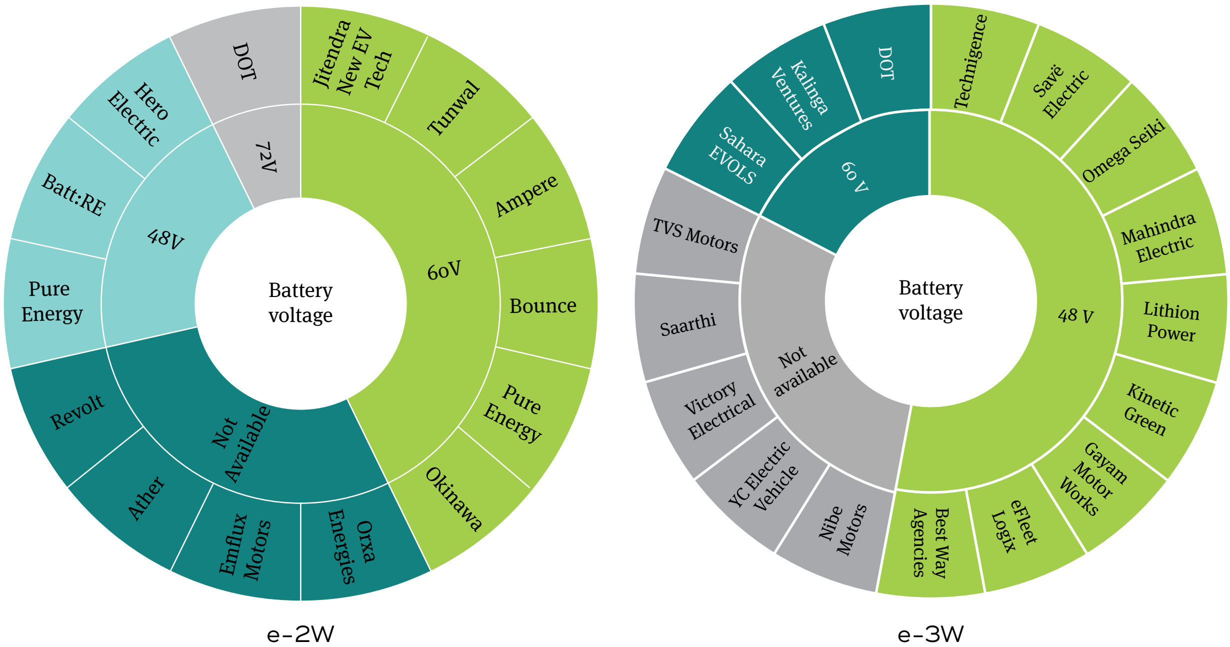
ES 6: BOX PLOT OF GOODS TRANSPORT E-3W BATTERY CAPACITY

Battery voltage, another important technical specification for an EV, which determines the charging voltage for the battery, varies between 48 volts (V) (lower limit) and 72 V (upper limit) for e-2Ws. The current guidelines specify 48 V as the output voltage for e-2Ws and e-3Ws. It is worthwhile to note here that the reason for adoption of 48 V as the standard voltage is linked to previous EV designs with lead acid batteries[4]. It was easier to retrofit models that had 48 V lead acid battery packs with corresponding lithium-ion battery packs. But as new EV models are emerging with lithium-Ion battery packs, it is important to consider the reality that there will be e-2Ws with higher voltage battery packs on the market. High voltage battery packs are more energy-efficient, as the higher the voltage, the lower the current and corresponding thermal losses. A sampling study of 15 EV models on the

4 Lead acid battery banks are manufactured in packs of 12 V, and the 48 V pack (4 x12 V) was common in EVs.

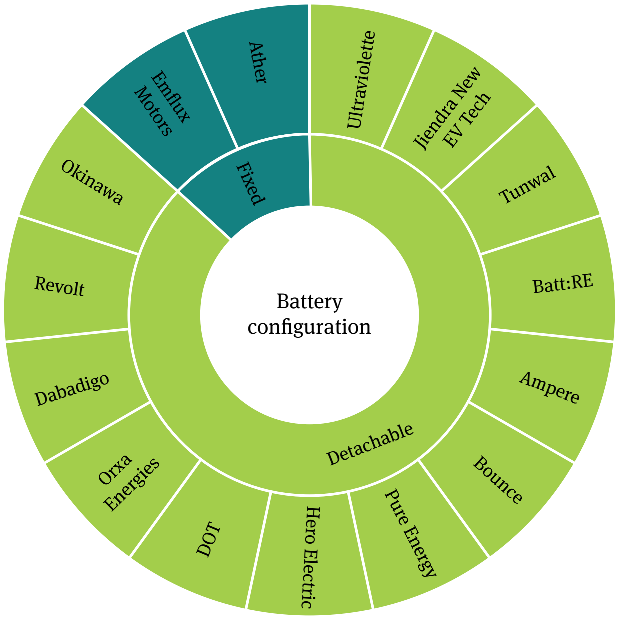
market showed that there are vehicle models with 60 V and 72 V battery packs (Figure ES 7). There is therefore a need to develop standards and deploy charging facilities suitable for e-2Ws with battery voltages above 48 V.

In case of e-3W models, the voltage of the battery packs is between 48 V and 60 V (Figure ES 7).



ES 7: BATTERY VOLTAGE IN E-2W AND E-3W MODELS

To assess the charging requirement of e-2Ws and e-3Ws, an important factor to study is the battery configuration of the vehicles. A key feature of India's e-2W and e-3W market is the availability of models with detachable batteries, apart from models with fixed batteries (Figure ES 8, Figure ES 9). The choice of charging technologies or methods depends primarily on battery configuration. For instance, if the battery is detachable, battery swapping appears to be a preferred charging option, according to feedback from stakeholders. Hence, for the purpose of studying charging technologies, classification should be based on whether the vehicles have fixed batteries or not. In the case of EVs with fixed batteries, plug-in charging is the only possible way of charging the vehicle, whereas both plug-in charging and battery swapping are possible for e-2Ws and e-3Ws with detachable batteries.



ES 8: BATTERY CONFIGURATION IN E-2W MODELS WITH LITHIUM-ION BATTERIES

ES 9: E-3W BATTERY CONFIGURATION

Methods for e-2W and e-3W Charging

e-2Ws and e-3Ws are distinct in design from the other classes of EVs in both their powertrain and battery related aspects. There are hardly any international standards governing the design of e-2Ws and e-3Ws. Hence, there is no standardisation of charging practices worldwide for these vehicles. The Indian market presents an opportunity to develop effective home-grown charging solutions for e-2Ws and e-3Ws. Hence, it is important to understand how these light EVs are currently being charged in India.

Both fixed and detachable batteries can be charged inside EVs with fixed or portable chargers. If the vehicle has an on-board charger, it can be plugged into the nearest power outlet to charge the battery. An alternative for vehicles without on-board chargers is to use off-board fixed or portable chargers. If the battery is detachable, there is an additional option for charging, namely, battery swapping. Battery swapping entails removing the depleted battery from the EV, replacing it with a spare recharged battery, and recharging the depleted battery outside the EV with a battery charger. The battery recharging can be done individually using a portable charger or in a pack using a fixed stack battery charger. The e-2W and e-3W charging methods are presented in Figure ES 10.

Plug-in Charging (Fixed or Detachable Battery)*		Battery Swapping (Detachable Battery)#	
Fixed EVSE	Portable EVSE	Individual Battery Charging	Stack Battery Charging

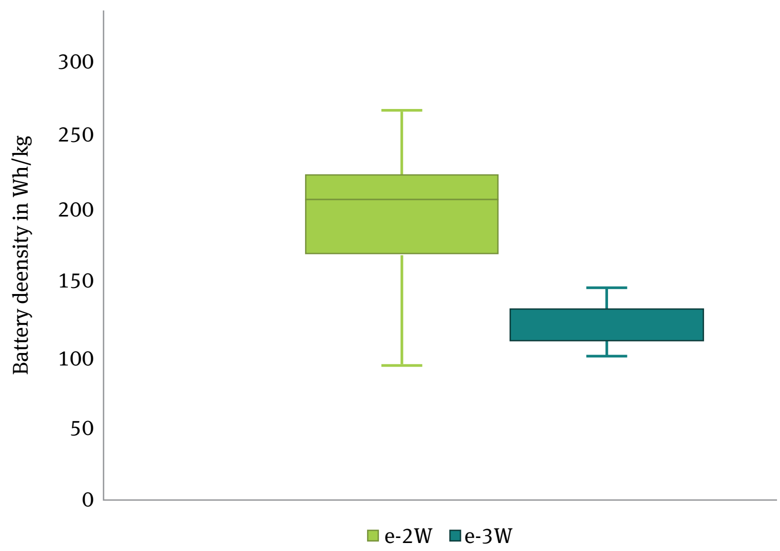
ES 10: E-2W AND E-3W CHARGING METHODS

** Charging inside EV*
 # Charging outside EV

Battery Swapping, An Emerging Frontier for Charging Service Providers

The battery swapping system consists of the battery charging system and battery swapping mechanism. In the case of e-2W and e-3W battery swapping systems, the swapping can be done manually, which enables less complex and more cost-effective swapping operations than in the case of e-4Ws or e-buses.

The weight of the battery pack is an important factor when it comes to swapping operations. This weight depends on the battery capacity and energy density of the battery pack. Battery pack energy density is not a parameter that is commonly reported by manufacturers in their product brochures. Mapping of the specific battery energy densities of FAME-II approved e-2W and e-3W models shows that energy densities of 200 Wh/kilogramme (kg) and 125 Wh/kg are good representative indicators of the e-2W and e-3W models, respectively (Figure ES 11). The FAME guidelines have set a density of 70 Wh/kg as the minimum threshold for eligibility for demand incentives.



ES 11: ENERGY DENSITY OF FAME-II APPROVED E-2W AND E-3W MODELS

With higher energy density and lower battery capacity, the e-2W battery packs are typically lighter than the e-3W battery packs. A typical 2 kWh e-2W battery weighs anywhere between 8.8 and 11.4 kg[5]. The lower the battery weight, the easier it is to manually lift it. It is also possible to split a battery into two smaller battery packs of 1 kWh each; this improves the ease of battery lifting and handling.

In the case of e-3Ws, the battery size is around 3 kWh for passenger e-rickshaws and 5 kWh for goods carriers. The associated weights of these batteries are 20 - 30[6] kg and 33 - 50[7] kg, respectively. The weight complicates e-3W battery swapping operations.

Generally, battery charging can be done at the same location as the swapping facility, with the help of portable or fixed chargers. The specifications for fixed battery chargers are quite similar to those of portable EV chargers. In the stack chargers, sometimes also called modular or bulk chargers, there are many dockets where the individual batteries are placed for charging.

It is also possible to develop a hub-and-spoke model for battery swapping. In this case, centralised charging is done in a remote location, and the swapping facilities only dispense the charged batteries. In such cases, a high tension (HT) grid connection may be needed, based on the number of batteries. The ancillary infrastructure includes the suitably rated transformer, circuit breaker, and cables. The charged battery dispenser for 20 batteries can be installed in an area of 1 sqm.

1.4 e-2W and e-3W Charging – A Testing Crucible

The e-2W and e-3W charging service sector in India is growing in its own unique manner and quite differently from the e-4W market. Because of the much smaller battery sizes compared to those of e-4Ws, not only can e-2Ws and e-3Ws, i.e. Light Electric Vehicles (LEVs), be charged in a reasonable time without sophisticated fast plug-in charging technologies, but, due to the lighter weight of their batteries, they can also be easily charged using battery swapping techniques. Additionally, as there is less space required for LEV parking than for e-4W parking, e-2W and e-3W charging facilities can be deployed in areas with less available space and low voltage electricity connections (15 A sockets are sufficient). The average service/ business catchment area for LEVs is also much smaller than the area for e-4Ws. e-2Ws and e-3Ws are used for first- and last-mile connectivity, for example, whereas e-4Ws hardly have a role to play in this activity.

Due to the inherent flexibility in e-2W and e-3W charging, market players have been testing out unique charging methods, and such methods influence the choice of charging technology. It should be noted that the e-2W and e-3W market is dominated by small original equipment manufacturers (OEMs), fleet operators, and charging service providers. Often the defined role of each of these players is fuzzy, i.e. a manufacturer may also operate a commercial fleet or run a plug-in charging or battery swapping service. Table ES 12 provides a glimpse of the different charging techniques employed for

5 Calculated with 175 Wh/kg and 225 Wh/kg as lower and upper limits, respectively.
6 Calculated with 100 Wh/kg and 150 Wh/kg as lower and upper limits, respectively.
7 Calculated with 100 Wh/kg and 150 Wh/kg as lower and upper limits, respectively.

ES 12: DIFFERENT CHARGING PRACTICES ADOPTED FOR COMMERCIAL E-2WS AND E-3WS IN INDIA

Operating Entity	Plug-in EV Charging	Battery Swapping	Vehicle Category	Operational Category	Charging Service Operating Model
Ather	Distributed EV charging		e-2W	Passenger	Subscription model for customers; tie-ups with shops
Bounce		Individual battery swapping	e-2W	Passenger	Tie-up with kirana stores
Dabadigo		Individual battery swapping	e-2W	Passenger	Swapping facilities set up by fleet operator
DOT	Centralised EV charging		e-2W, e-3W	Logistics	Captive charging facilities set up by fleet operator
eFleet Logix	Centralised EV charging		e-3W	Logistics	Captive charging facilities set up by fleet operator
Gayam Motor Works		Stack battery swapping	e-3W	Logistics	Captive swapping facilities set up by fleet operator
Lithion Power		Stack battery swapping	e-3W	Passenger, Logistics	Battery charging and swapping
SUN Mobility		Stack battery swapping	e-2W, e-3W	Passenger, Logistics	Provides swapping service to vehicles using its proprietary batteries
SmartE	Centralised EV charging		e-3W	Passenger	Captive charging facilities set up by fleet operator
Ola Electric		Individual and stack battery swapping	e-3W	Passenger	Swapping facilities set up by fleet operator

commercial fleets in the country.

From the snapshot of the charging practices followed by the different fleet and charging service providers, certain pattern has emerged. For example, in the passenger e-2W segment, many companies have opted for decentralised charging systems to charge their vehicles, where they have set up either e-2W chargers or individual battery swapping kiosks. A key reason for this could be to cover the relatively large catchment area of passenger e-2W transport. The high cost of space rental in cities is also a factor in this regard.

On the other hand, there is a clear similarity in the charging practices of all the logistics fleet operators – central charging places, usually at warehouses, instead of distributed charging systems, which are common in the case of passenger LEVs. However, the charging technologies used by these logistics fleet operators differ – some have opted for plug-in vehicle charging, whereas others have adopted the battery swapping method. The choice depends on the logistics fleets' operational characteristics. In the case of passenger e-3W fleets, there is a greater preference for battery swapping.

1.5 Five Possible Types of e-2W and e-3W Public Charging Facilities

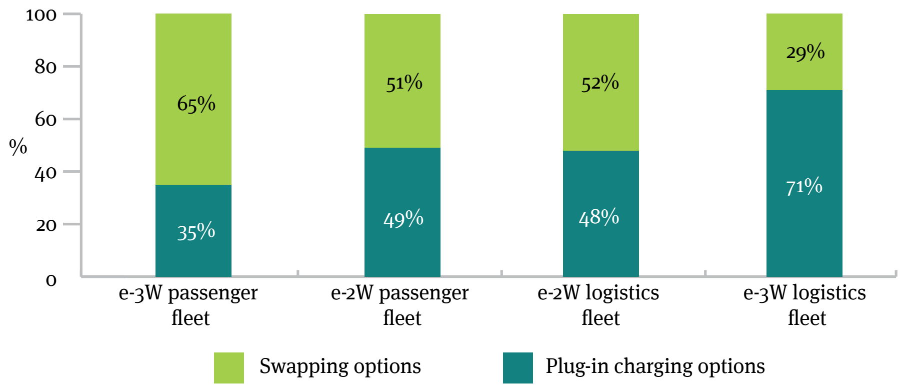
From the review of the charging practices observed in the LEV market, one can conclude that the choice of charging method depends entirely on the charging service provider's business model and/ or the e-2W/ e-3W fleet's operational characteristics when the fleet operator manages the charging of its own fleet. Both the business model and fleet's operational characteristics are found to vary. Hence, a "one-size-fits-all" approach to identifying the most suitable e-2W and e-3W charging methods is not appropriate. However, it is able to identify five salient types of public charging facilities for LEVs (Figure ES 13). Given that both plug-in charging and battery swapping are possible for e-2Ws and e-3Ws, the charging facilities for this segment should include these technologies.

Individual EV charging facility (EV)	▸ Can cater to the charging needs of one EV at a time ▸ Can be set up anywhere on the side of a road where an e-2W/ e-3W can be parked and charged ▸ Easier to set up, as the power requirement for this type of facility is limited to 3 kW
Individual battery swapping facility (IBS)	▸ Can cater to the charging needs of an individual e-2W or e-3W that has a swappable battery ▸ Similar to individual EV charging facilities and easy to set up ▸ Need to maintain a stock of spare batteries for the e-2Ws and e-3Ws
Multiple EV charging facility (MEV)	▸ Facilitates the charging of multiple e-2Ws and e-3Ws at the same time ▸ Can be set up in any parking area where adequate space is available to install the charging infrastructure ▸ A new electricity connection required to set up this type of charging facility
Stack battery swapping facility (SBS)	▸ Can cater to the charging needs of multiple e-2Ws or e-3Ws with swappable batteries ▸ Requires less parking space compared to MEV ▸ A new electricity connection required to set up this type of charging facility
Battery swapping-only facility (BSO)	▸ Offers swapping services without on-site battery charging, serving as a dispenser of charged batteries for swapping operations ▸ Easier to establish, as they can be set up anywhere without the requirement of an electricity connection at the site

ES 13: FIVE POSSIBLE TYPES OF PUBLIC CHARGING FACILITIES FOR LEVS

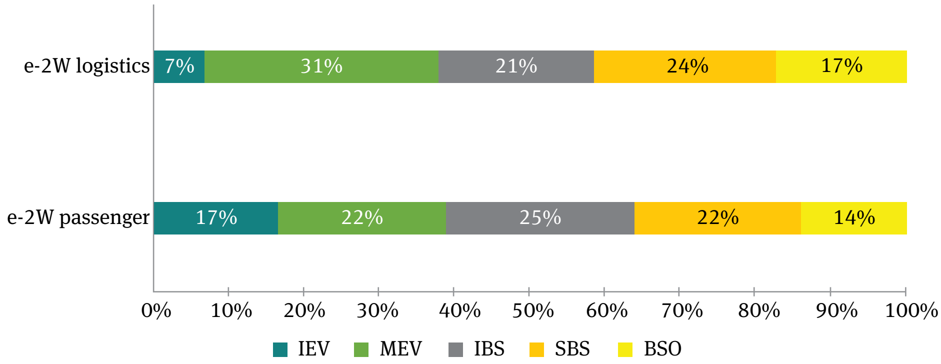
1.6 Charging Preferences of Fleets

An online survey conducted with fleet operators and charging service providers has deciphered some interesting patterns in their relative preferences for the different charging options. A summary of fleet preferences for plug-in charging and battery swapping is presented in Figure ES 14.

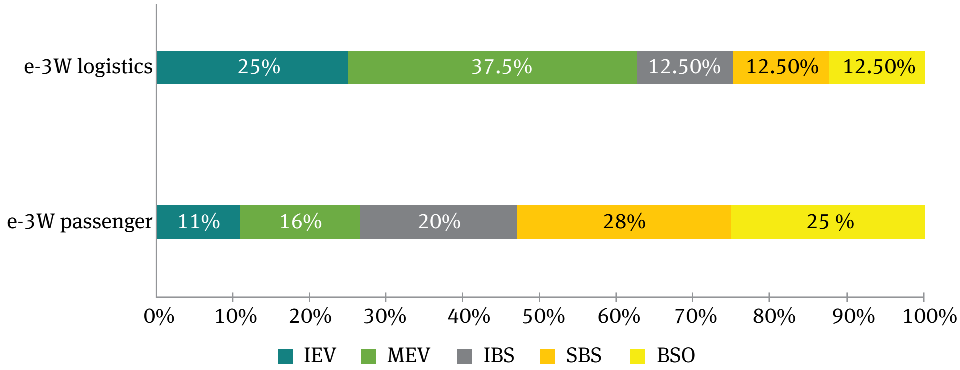


ES 14: FLEET PREFERENCES FOR EV PLUG-IN CHARGING AND BATTERY SWAPPING

The relative preferences of e-2W and e-3W fleet operators for different types of charging facilities are shown in Figure ES 15 and Figure ES 16 respectively.



ES 15: SUMMARY OF E-2W FLEET PREFERENCES



ES 16: SUMMARY OF E-3W FLEET PREFERENCES

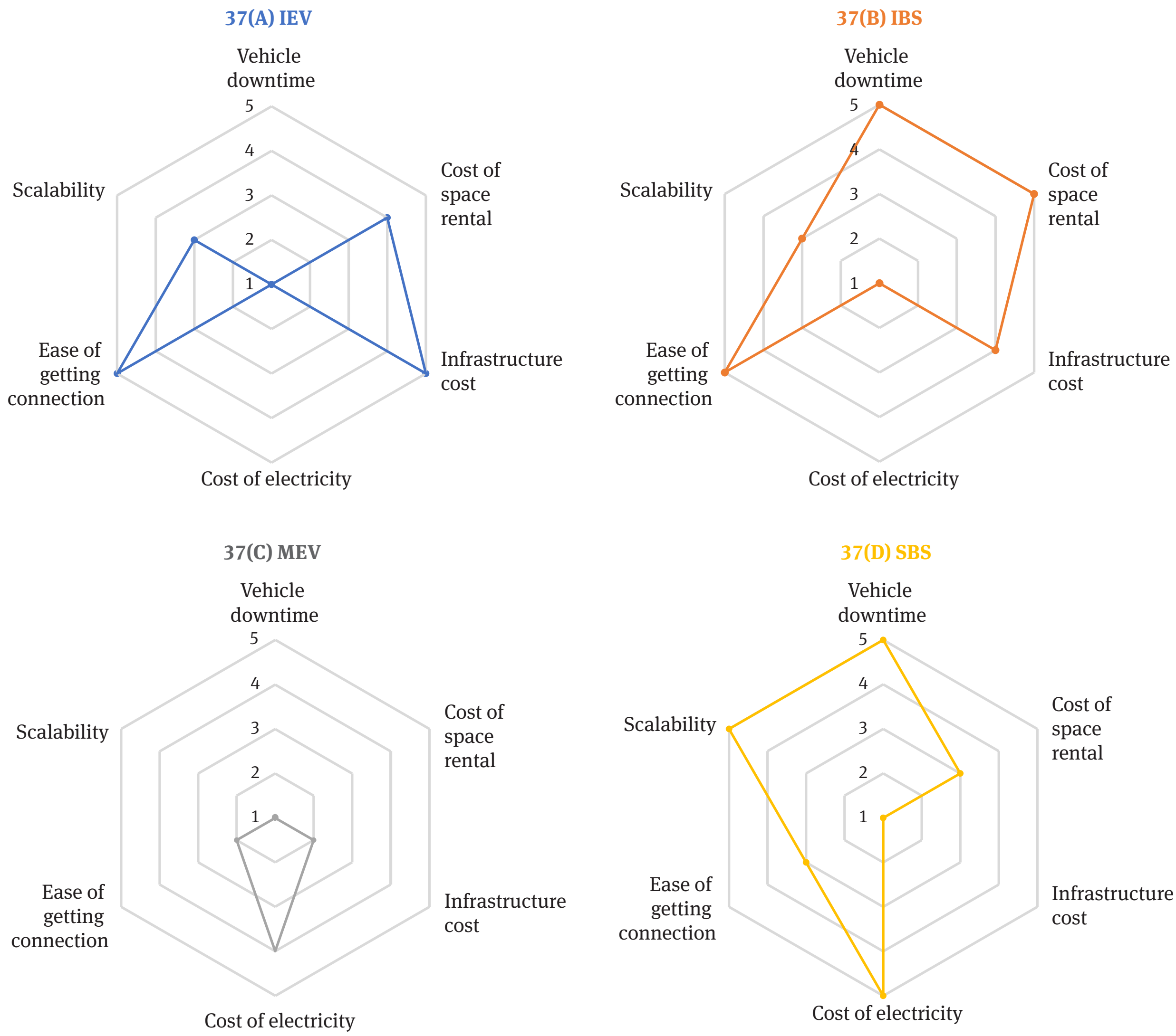
1.7 Trade-off between The Charging Facilities

Each of the 5 types of public charging facilities has its unique advantages, and the suitability for a particular fleet depends on how the advantages are leveraged in the fleet operations. Since the operational characteristics of these LEV fleets vary considerably, identifying a particular type of charging facility for all e-2W and e-3W fleets is not appropriate. A qualitative comparative assessment of these different charging facilities based on 6 parameters and using a scale of 1 to 5 (Table ES 17) provides some interesting results. This can potentially help charging service providers and fleet operators make an informed decision when choosing the type of charging facility. Accordingly, they can invest directly in the charging infrastructure for LEV fleets or tie up with a charging service provider or OEM.

ES 17: COMPARATIVE ASSESSMENT PARAMETERS AND SIGNIFICANCE OF THE SCALE

Parameter	Significance of the applied scale – what "5" means
Vehicle downtime	Least vehicle downtime for charging
Cost of space rental	Lowest cost incurred
Cost of infrastructure (excluding space)	Lowest infrastructure cost
Cost of electricity (tariff)	Attracting lowest tariff
Ease of getting electricity connection	Easiest to get electricity connection

Scalability (ability to cater to the charging requirement of numerous fleets)	Easiest to scale up



ES 18: SUMMARY OF SCORES OF DIFFERENT TYPES OF PUBLIC CHARGING FACILITIES

Figure ES 18 provides an overview of the scores of the different types of LEV public charging facilities[8] for the 6 identified parameters.

It should be noted that Figure ES 18 does not intend to recommend a particular type of public charging facility nor rank the different options, but, rather, to show the strengths and challenges of the different types of facilities in terms of key parameters.

The need of the hour is to design and implement cost-effective, scaleable, and home-grown charging solutions that can meet the charging requirements of the LEV segment.

8 The BSO option has not been included in this assessment, since this facility only performs the swapping operation and therefore is not comparable to actual charging facilities.