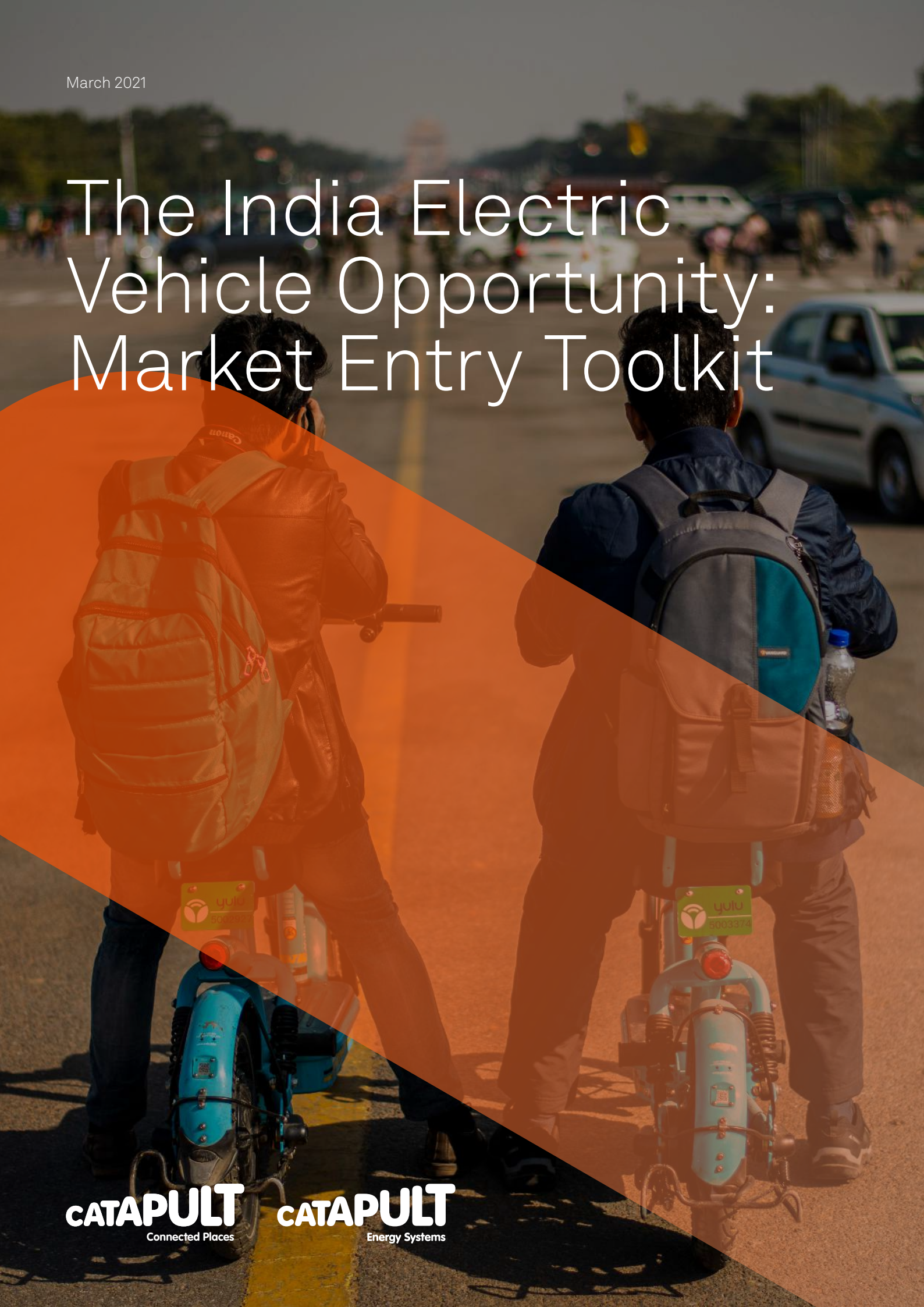
March 2021

The India Electric Vehicle Opportunity: Market Entry Toolkit



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CATAPULT Energy Systems

Authors

Lovedeep Brar
Bob Burgoyne
Lovisa Eriksson
Rimaljit Likhari
Thalia Skoufa
Lowri Williams

Acknowledgments

The authors would like to thank the following individuals and organisations for their valuable contributions to this report (errors or omissions remain the responsibility of the authors):

Ms. Sonal Bhartia, Director, Investment Banking Advisory, EY

Shipra Bhutada, Founder, User Connect Research Agency, Benagluru

Debi Prasad Dash, Executive Director, IESA

Manoj M Desai, General Manager - Automotive Electronics Department, ARAI

Shalendra Gupta, CFO, Altigreen Propulsion Labs

Raghav Handa, Director-Business Corridors, Asia Pacific, HSBC

Aman Hans, Lead Consultant - National Energy Storage Mission, NITI Aayog

Mark Hartmann, CTO Latent Heat Solutions

Ashutosh Humnabadkar, SVP, eMobility, Quanzen

Sumeet Jain, Head of UK Outbound India Desk, HSBC

Amit B Jain, International Director, EY-UK

Ankit Kumar, CEO, GoZero Mobility

Harsha Lingam, COO, Global Business Inroads

Siddharth Mukne, Associate Director, UKIBC

Mr. Gaurav Sahgal, Managing Director and Head of International Subsidiary Business, HSBC India

Vivek Sharanappa, Co-founder and CEO, BuyMyEV

S R Venkatesan, MD, Transvahan Technologies

Professor Dr Ashish Verma, Associate Professor, Transportation Systems Engineering (TSE) and Convenor, IISc Sustainable Transportation Lab (IST Lab), Indian Institute of Science (IISc)

Project partners: Enzen, Project Lithium, Shakti Foundation, Fields of View, Everything Eco, WRI, ISGF, UrbanMorph, C40 Cities, Benagluru Directorate of Urban Land Transport, Shell's E4 Accelerator Programme

Other organisations: SunMobility, Ather Energy, Bounce, The Energy and Resources Institute (TERI), The Confederation of Indian Industry

Executive Summary

I. Market Overview

- The automotive sector in India is dominated by two-wheelers (scooters, motorbikes) and three-wheelers (autos and rickshaws) that play a significant role in last mile mobility in the country. At 22 cars per 1000 people, car ownership is low, while two-wheeler ownership is among the highest in the world.
    - While electric vehicles (EVs) currently account for less than 1% of total vehicle sales in India the market is growing rapidly and expected to be worth around at least £4.8 billion (INR 475 billion) by 2025. Two-wheelers account for the largest share of this market at 62%, followed by three-wheelers at 37%.
    - The Indian EV market varies significantly by state, depending on factors including demographics, income levels, regulatory landscape and urbanization. The state of Uttar Pradesh, for instance, with one of the lowest urbanisation rates, has seen significant uptake of electric two-wheelers. Maharashtra, on the other hand, with a higher urbanisation rate, has the highest penetration of electric three-wheelers and passenger cars.
- The penetration of **electric two-wheelers** is projected to reach up to 15% by 2025 from 1% currently.
    - Low to medium speed electric two-wheelers (up to 40 kmph) with lead-acid batteries currently dominate the market but demand for Lithium-ion battery models is expected to grow rapidly under government incentives and demand from bike and scooter rental companies such as Vogo, Yulu and Bounce.
    - Many OEMs have launched high-speed (>40km/h) electric scooters; two (Ather and Okinawa) successfully fulfilling the local manufacturing requirement under the FAME II scheme and thereby unlocking subsidies. Hero Electric, Ather Energy, Ampere, Okinawa, are establishing manufacturing units throughout the country.
- **Three-wheelers** are the dominant mode for last mile connectivity in several states including Delhi, Bihar, West Bengal and Uttar Pradesh and the electric three-wheeler market is expected to grow rapidly. Further growth potential lies in converting pedal rickshaws.
    - While most electric three wheelers are primarily low speed, growth is expected in the high-speed market, particular for the cargo segment.
    - The battery swapping model for supplying power has side-stepped the lack of charging infrastructure but the future is likely to see a mix of both models.

- With the push from government for ICAT-certified models from late 2018, the share of larger players in the e-rickshaw segment (e.g. Mahindra Electric, Kinetic Green and Lohia Auto) is gradually growing.

    - **The four-wheeler segment** currently has the lowest EV penetration of 0.12% (3,400 units of electric passenger cars sold in 2020) but may grow to 5% by 2025 in an optimistic scenario. The demand in the short to medium term will be driven by fleets - including taxi and goods delivery services. For the commercial fleet segment, penetration is forecast to range between 20%-30%).

- Factors such as limited market offerings, high upfront costs, insufficient battery life, high dependency on imports (with associated high tariffs), low range, power outages and crucially, an underdeveloped charging ecosystem continue to impede a higher penetration in the four-wheeler consumer segment.

- The electric four-wheeler market is currently limited to only four OEMs but several new players, domestic and international, are planning to launch their models over 2021-22. Two OEMs - Hyundai and MG Motor - currently import their EVs to India as CBUs or SKD (see glossary). In contrast, Tata Motors and Mahindra Electric manufacture locally.

    - **EV components** present a market opportunity of another £2bn by 2025. Currently, EV manufacturing in India is being largely supported by imported components. However, large OEMs are making moves to enter the EV components market to reduce reliance on imports and meet the 50% localisation criteria to access government subsidies.

Market Drivers and Barriers

The key market drivers and barriers with regards to increasing EV penetration and success in India are summarised in Table 1.

Drivers	• Favourable government policies and subsidies • Heavy investments from automakers • Increasing diversity of products widening appeal to different groups • Growing awareness of air quality and environmental issues • Rising income levels in Tier-1 cities • Lower Total Cost of Ownership (TCO) for EVs as compared to ICE
Barriers	• Complex criteria and processes to benefit from government incentives (demand and supply-side) • Recent decline in economic activity on account of COVID-19 • Low consumer spending power outside Tier-1 cities • Lack of raw material limits domestic battery manufacturing • Slow roll-out of charging infrastructure • High upfront costs of electric four-wheelers compared to ICE vehicles • Electricity network reliability issues

Table 1 India EV Market: Drivers and Barriers

II. Opportunities and Understanding the Consumer

The EV transition in India opens up a range of opportunities for UK companies across services, vehicles, battery supply chain, charging infrastructure, and the electricity system. In general, these opportunities would be best pursued through a joint venture or other partnership with a local entity. Selected opportunities include:

Services and Solutions

- First and last mile micro-mobility and shared mobility EV services have potential (particularly for female travellers) offering opportunities for software providers for route-optimisation tools.
- Solutions to managing charging and range anxiety:
    - Analytics solutions to understand current range left given weather and traffic conditions.
    - Journey planning tools which incorporate planning for battery re-charging or swapping.

Electric Vehicles

- Cutting edge design and innovation in various elements of components manufacturing including electrical steel, cells, batteries and battery management systems.
- Fleet optimisation software and services for ride-sharing, employee transport and last-mile freight companies.
- Vehicle sales, particularly premium offerings targeting the top end of the market.

Charging Infrastructure

- Mass market adoption of EVs requires a charging infrastructure that is affordable, accessible and serves all consumer groups.
    - Partnering with Indian vehicle OEMs to provide charge point hardware and software could be a route to market for UK charge point manufacturers.
    - Specific opportunities include affordable and reliable public charging infrastructure, with appropriate considerations for the Indian market (e.g. two/three-wheeler compatible); battery swapping technologies, and online platforms for charging infrastructure visibility.

Energy System

Supplying 'green' electricity for EV charging and taking advantage of the flexibility offered by EVs are longer term targets for India. Although the electricity market would need change to enable flexibility solutions, there are some areas where innovation is needed today, and UK companies

can potentially find opportunities in the following areas:

- Solutions to deliver consumer propositions that successfully access flexibility[i], in particular related to EV charging.
- Tools that provide a richer understanding of how transport, power, energy and town planning interlink and can be coordinated.
- Systems that improve the understanding and visibility of current and future states of the Indian energy system.
- Automatically controlled interventions; storage, compensation and filtering.
- Technologies to decouple the grid from charging demands.

The Indian EV consumer

- The Indian (mass) market is very price sensitive. Working to incorporate local components in order to access subsidies can help - as well as highlighting potentially cheaper total ownership costs.
- EVs are generally well suited to Indian driving conditions; points to emphasise for product launch. However, ensuring that safety and performance is delivered in the context of a variable climate, poor roads and a start-stop driving style is important. Test-drives can help provide reassurance.
- Prospective consumer customers have concerns about battery life and charging availability - which are often not material given the likely usage profile in India. Nonetheless, software for route planning and information on charge point locations may alleviate concerns.
- Usage is heavier amongst professional drivers; battery swapping provides an interim solution and there will be a ready market for fast-charging solutions when they become price competitive.
- Consumer customers worry about accessing servicing and maintenance support for their EVs: consider bundling these with the vehicle purchase.
- Vehicle ownership is an importance badge of status in India with larger private vehicles being prized. To encourage adoption of electric micro-mobility solutions or 2-wheelers, help owners signal their eco-credentials, something which is also socially desirable.
- The user experience of EVs depends on the ecosystem as a whole - important to engage and build partnerships therefore to help prevent a poor experience which isn't within direct control.

i Flexibility is defined as 'modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system'. For more info, read here (OfGem, 2020)

III. Policy and Regulatory Environment

- FAME-II is the Indian government's flagship policy to encourage the adoption and manufacturing of EVs in India (part of the 'make in India' push). The policy offers subsidies to manufacturers as well as to consumers to buy an 'eligible' EV at a reduced price.

- However, EVs need to meet several eligibility criteria to benefit from the subsidies, including minimum range, acceleration and maximum speed. Another challenging criterion for manufacturers is that more than 50% of components should be locally manufactured.

- For four-wheelers, incentives are only offered to vehicles used for public transport or for commercial purposes.

- EVs in India attract a lower Goods and Service Tax (GST) of 5% (reduced from 12% in 2019), compared to 28-43% for internal combustion engine vehicles.

- The government plans to make it mandatory for ride-sharing companies such as Ola and Uber to 'electrify' at least 40% of their fleets.

- Several state governments have introduced their own EV policies to attract investment. States like Andhra Pradesh, Uttar Pradesh, Tamil Nadu and Gujrat offer incentives such as capital interest subsidies, stamp duty reimbursements, tax exemptions and interest free loans.

Legal & Compliance

India has one of the highest import tariffs on vehicles (particularly cars) in the world. In line with efforts to localise the EV supply chain, the government has increased customs duty on most imported EV components.

- Companies looking to access demand incentives (subsidies) under the FAME-II scheme, are required to gradually increase local sourcing of components for their EVs.

- India has standards and certification requirements in place for EV components/systems. Most are aligned with International Standards with the exception of some reflecting local use and environment; for example tests to demonstrate protection from flood and rain damage.

- India is a signatory to international IP agreements and while legislative protection is comparable to Europe, bureaucratic delays in enforcement mean that practically speaking, this is a problematic area and India's ranking in the International Intellectual Property (IIP) Index is low.

Contents

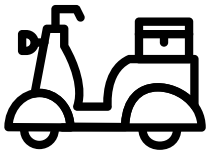
1. Definitions

Electric two-wheelers: (e-2W) Include electric-scooters (two-wheeled vehicle with a step-through frame) and electric-motorcycles. Two-wheeled vehicles with maximum speed of less than 25km/h do not currently require a licence or a registration plate.

Electric three-wheelers (e-3W): Categorised based on their top speed; e-rickshaws have a top speed of 25km/h whereas e-autos have a maximum speed allowance of 60km/h. 3 wheeled vehicles are also used for short haul goods deliveries.

Electric four-wheelers (e-4W): The electric four-wheeler category includes passenger vehicles and light commercial vehicles. Available models from Indian and foreign manufacturers vary on top speed and battery size. Electric pick-up trucks are also entering the market.

2-wheelers



E-scooter

E-motor cycle

3-wheelers

E-auto

E-rickshaw

Goods carriage

4-wheelers

Passenger car

Light commercial vehicle

AC power	Alternating Current power involves periodically changing direction of electric charge (current). The voltage in AC circuits also periodically reverses because the current changes direction.
Advanced Battery	Advanced Battery (as defined by the Indian government) represents the new generation batteries such as Lithium polymer, Lithium Iron phosphate, Lithium Cobalt Oxide, Lithium Titanate, Lithium Nickel Manganese Cobalt, Lithium Manganese Oxide, Metal Hydride, Zinc Air, Sodlum Air, Nickel Zinc, Lithium Air, under development or in use. In addition, this battery should have specific density of at least 70 Wh/kg and cycle life of at least 1000 cycle.
BCD	Basic Customs Duty is a type of duty or tax imposed under the Customs Act (1962). Basic Customs Duty varies for different items from 5% to 40%.
BEV	Battery Electric Vehicles are fully electric with rechargeable batteries and no fuel engine. They store electricity onboard with high-capacity battery packs. Their battery power is used to run the electric motor and all onboard electronics.
BMS	Battery Management System – the brain of a battery pack – measures critical parameters and controls them to keep the battery safe and operate efficiently. Batteries, without a good BMS, are suboptimal in performance, life and safety. BMS constitutes 10-15% of total battery costs.
BOP	Balance of Pack, a key component of batteries, includes thermal management and mechanical components like housing, etc. Constitutes 15-20% of battery costs.
CAGR	Compound Annual Growth Rate
Commercial Vehicles	Vehicles registered for commercial use such as taxi services, employee transport, corporate fleet and freight distribution.
CBU	Completely Built Units refer to imported/exported vehicles which are bought as fully assembled, complete units. These vehicles do not require assembly before they can be sold to buyers in the importing country's markets. Most imported cars and bikes in India come as CBU.
Cells	A cell is the most basic unit of a battery pack. Each cell has an anode and a cathode separated by a separator. A number of cells put together form a module and a number of such modules put together build a battery pack.
CKD	Completely Knocked Down vehicle is one which is imported or exported in parts and not as one assembled unit. Such units are first sent to an assembly plant in the target country where all these parts are assembled, and one complete vehicle is made using the imported components.
CMVR	Central Motor Vehicles Rules, published in 1989 by the Ministry of Road Transport, Highways & Shipping (MoRTH&S) and govern vehicle-related activities such as driver licensing, traffic inspections, production and maintenance of motor vehicles, as well as licensing of automotive components and entire vehicles.
Demand Incentives	Demand incentives (under FAME-II) are meant for consumers (buyers/ end users) in the form of an upfront reduced purchase prices of hybrid and electric vehicles to enable wider adoption, reimbursed to the OEM by Government of India.
DC power	Direct Current power involves one-directional flow of the current.
DTA	Domestic Tariff Area refers to an area in India outside the Special Economic Zones (SEZs) and other export-oriented parks/zones.
EPF	Employees Provident Fund (EPF), contributions made by both employers and employees.

Electric Drive Technology	Converts electrical energy from the power supply system or from a battery into mechanical energy and transmits the resulting force into motion.
Electric Regenerative Braking System	An integrated vehicle braking system which provides for the conversion of vehicle kinetic energy into electrical energy during braking.
ESCOM	Electricity Supply Company
EV	Electric Vehicle
EV Controller	Acts as an intermediary between a battery and a motor that estimates how much energy needs to be supplied to the motor for the EV to function smoothly.
FAME-I	The first phase of Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles scheme (FAME) that ran from 2015 to 2019 and aimed to promote manufacturing of electric and hybrid vehicle technology. For more information, read here.
FAME-II	Second phase of the FAME Scheme which cost Rs. 10,000 Crore (£1 billion); offers subsidies to EV buyer and OEMs, and establishes charging infrastructure (2700 charging stations across 62 cities).
FCI	Fixed Capital Investment is the portion of total capital outlay of a business invested in physical assets such as factories, vehicles, and machinery that stay in the business almost permanently, or, more technically, for more than one accounting period.
Flexibility	Flexibility (in the context of electricity) is defined as modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system.
GDP	Gross Domestic Product is the total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period.
GVW	Gross Vehicle Weight is the value specified by the manufacturer as the maximum total loaded weight of a single vehicle.
ICE vehicle	Internal Combustion Engine vehicle
INR	Indian Rupee
IP	Intellectual Property
JV	Joint Venture
LCV	Light Commercial Vehicles in India are cargo vehicles with a gross vehicle weight (GVW) of less than 3,500 kg. Largely used for last-mile goods delivery in India, LCVs are categorized as N1 vehicles as per CMVR.
Lead-Acid Battery	A rechargeable battery that uses lead and lead oxide as the cathode and anode, respectively, and sulfuric acid as the electrolyte.
Li-ion battery	A rechargeable battery that uses lithium ions as a key component of its electrochemistry.
LLP	Limited Liability Partnership is a form of corporate structure/legal entity separate from its partners. Foreign nationals, including foreign companies and LLPs, can incorporate an LLP in India, provided at least one designated partner is a resident of India. For more info, read here.
LV network	Low Voltage Network is a part of electric power distribution which carries electric energy from distribution transformers to electricity meters of end customers. LV network are operated at a low voltage level, which is typically equal to the mains voltage of electric appliances.
Mild Hybrid	Mild hybrids are generally cars with an internal combustion engine equipped with an electric machine allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly.

MEIS	Merchandise Exports from India Scheme is an Indian Government scheme designed to provide rewards to exporters to offset infrastructural inefficiencies and associated costs.
MoP	Ministry of Power
MSME	Micro, Small and Medium Enterprises, with turnover up to INR 1 crore, Rs 10 crore and INR 50 crore, respectively. For more info, read here.
NMT	Non-Motorised Transport includes walking and cycling, and variants such as small-wheeled transport (cycle rickshaws, skates, skateboards, push scooters and hand carts) and wheelchair travel.
OEMs	Original Equipment Manufacturer is a company that manufacturers systems or components that are usually used in another company's end product.
On-board chargers	On-board chargers enable users to charge vehicles by plugging them into an AC source, either at home or at public charging stations.
Passenger Cars	A passenger car, as defined by the OECD, is a four-wheeler intended for the carriage of passengers and designed to seat no more than nine persons (including the driver).
PHEV	Plug-in hybrid electric vehicle is a hybrid electric vehicle whose battery can be recharged by plugging it into an external source of electric power, as well as by its on-board engine and generator.
PIS	Project Import Scheme is an Indian program to facilitate setting up of and expansion of industrial projects.
PMP	Phased Manufacturing Program launched by Indian Govt. in 2016-17 aims to increase the share of locally procured components in the manufacturing to the setting up of a robust indigenous manufacturing ecosystem in India.
Range	The expected distance a vehicle can drive with a fully charged battery under 'normal' conditions.
REII	Rajasthan Electronics & Instruments Limited
SEIS	Service Exports from India Scheme is an Indian Program that aims to promote export of services from India by providing duty scrip credit for eligible exports
SGST	State Goods and Services Tax
SKD	Semi Knocked Down are partially stripped down 'finished' vehicles, reassembled in target/importing country. SKD vehicles help manufacturers save taxes in the importing country. Most countries levy more than 100% tax for fully assembled (CBU) vehicles.
Stator Winding	Stator winding refers to the winding installed on the stator, that is, copper wire wound around the stator, an important part of motor. The stator consists of three parts: stator core, stator winding and machine base.
Strong Hybrid	Also called full hybrid, is a EV that can run either using combustion engine alone or only on an electric motor, or a combination of both.
TCO	Total Cost of Ownership is the purchase price of an asset such as vehicle plus the costs of operation over its life (eg including fuel, maintenance).
Well-to-wheel emissions	Well-to-wheel emissions include all emissions related to fuel production, processing, distribution, and use.
WTO	World Trade Organisation

2. Introduction

Throughout history, as places have grown and flourished economically, they tend also to have seen negative environmental outcomes. A construction boom will increase dust pollution. A greater demand for electricity is served by 'dirty' sources such as coal-fired power stations. Economic growth tends to drive the adoption of private vehicles, with the associated increase in emissions and impact on air quality. Through the Innovating for Clean Air (IfCA) programme, three UK Catapult organisations - Energy Systems, Connected Places and Satellite Applications - are supporting Bengaluru, India in its aspirations to address these challenges through the adoption of innovative new technologies and policy interventions.

One critical area, which is a high priority for both national and state government in India, is supporting the transition to electric vehicles. Through the national FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) schemes, and state-level equivalents, the Indian government has signalled a strong commitment to growing the sector and reducing the carbon-intensity of transport, in line with its targets under the Paris Climate Agreement. Fortunately, this is also an area where UK companies have a lot to offer - be it new battery technologies and management systems, electric micro-mobility solutions or software solutions to better manage EV fleets or the electricity grid.

This report is therefore intended to highlight the opportunity which India represents to the firms in the UK EV ecosystem and provide practical guidance on how to access it. In doing so it seeks to help UK firms build more linkages with their Indian counterparts, many of which have already been established through the IfCA programme as well as the wider UK-India tech partnership.

We provide an overview of the current status of and projected growth trajectories of various elements of the EV ecosystem - ranging from electric bikes to vehicle components through to the charging infrastructure and electricity grid itself. We look at the key companies operating in each sector and consider the fit between current market gaps and the capabilities the UK has to offer. Finally, we summarise the policy and incentives landscape to help companies navigate the complex array of institutions which certify vehicles, set tariffs and duties and provide subsidies and other incentives to different parts of the ecosystem.

In the final section of the report, we profile two companies who have successfully entered this rich and engaging market - and hope that many more will follow.

The Catapult Network supports businesses in transforming great ideas into valuable products and services. We are a network of world-leading technology and innovation centres established by Innovate UK. We deliver impact across the UK economy, enabling businesses to thrive in global markets. If you would like to learn more about what we do or the opportunity which India represents, please get in touch.

Andrew Stokes: Andrew.stokes@es.catapult.org.uk

Bob Burgoyne: Bob.burgoyne@cp.catapult.org.uk

3. Mobility in India

Travelling within and between places in India is a rich and varied experience and the mobility sector has significant differences to that in the UK.

Car ownership is very low (approximately 22 cars per 1000 people), whereas ownership rates for two-wheelers and three-wheelers are among the highest in the world. A wide range of vehicles are used in Indian cities; from two- and-three wheelers (rickshaws - either pedal or largely powered by CNG (compressed natural gas) or diesel) used for last mile transportation to taxis, buses and vans. Two-wheelers account for more than 75% of the 250 million vehicles registered in India, representing the second largest market globally for two-wheelers, second only to China (Forbes, 2019)[1].

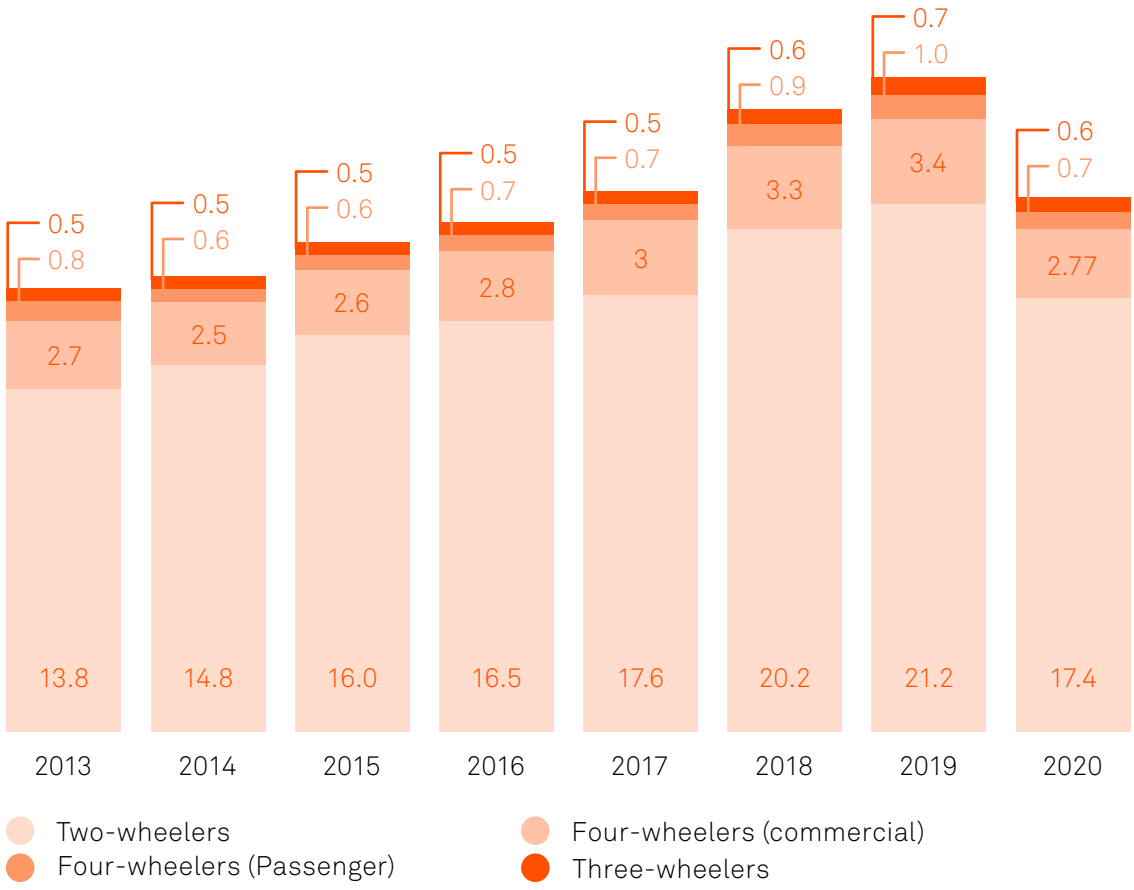


Figure 1 India: Unit sales of automobiles by type (FY 2013-20, million) (Source: SIAM India, 2020)

In terms of market growth, domestic sales (i.e., excluding exports) have grown at a rate of 1.2% between FY2015-20 with 21.6 million vehicles sold in FY20. 80% of the sales were two-wheelers and 16% four-wheelers including passenger and commercial vehicles.

From a manufacturing perspective, India is the world's fourth largest manufacturer of passenger cars and seventh largest manufacturer of commercial vehicles as of 2019. Domestic manufacturing has grown at 2.4% between FY2016-20 with 26.4 million vehicles manufactured in FY2020 (IBEF, 2020)[2].

Transport is a major contributor to air pollution in India, and many cities suffer from severe congestion during peak hours. On average, the peak hour travel speed is 15-20 km per hour in Indian cities (Verma et al. 2015).

3.1 Travel Behaviour

Despite the recent upsurge of personally owned vehicles in India, non-motorised (i.e., walking or cycling) and public transport remain the most common modes of travel. In 2011, the Census of India[3] revealed that most of those who travel to work do so by non-motorised transport (NMT) modes, such as walking and cycling (around 49% in urban areas). Two-wheelers and four-wheelers were used for 20% and 5% of work trips, respectively, in urban regions. Public transport accounted for around 20% of work trips, while taxi services (including rickshaw services) took 4.2% of the share[4]. According to Ola Mobility Institute (2019a:7), "the highest proportions of passenger-km travelled (for all purposes in India) are by public and shared transport vehicles (bike taxis, auto-rickshaws, taxi-cabs, and buses)."[5] This stands in stark contrast to travel in England, UK, where nearly 75% of all trips are undertaken by car[ii], with walking and bus travel at second and third place (8.4% and 7.1% respectively)[6].

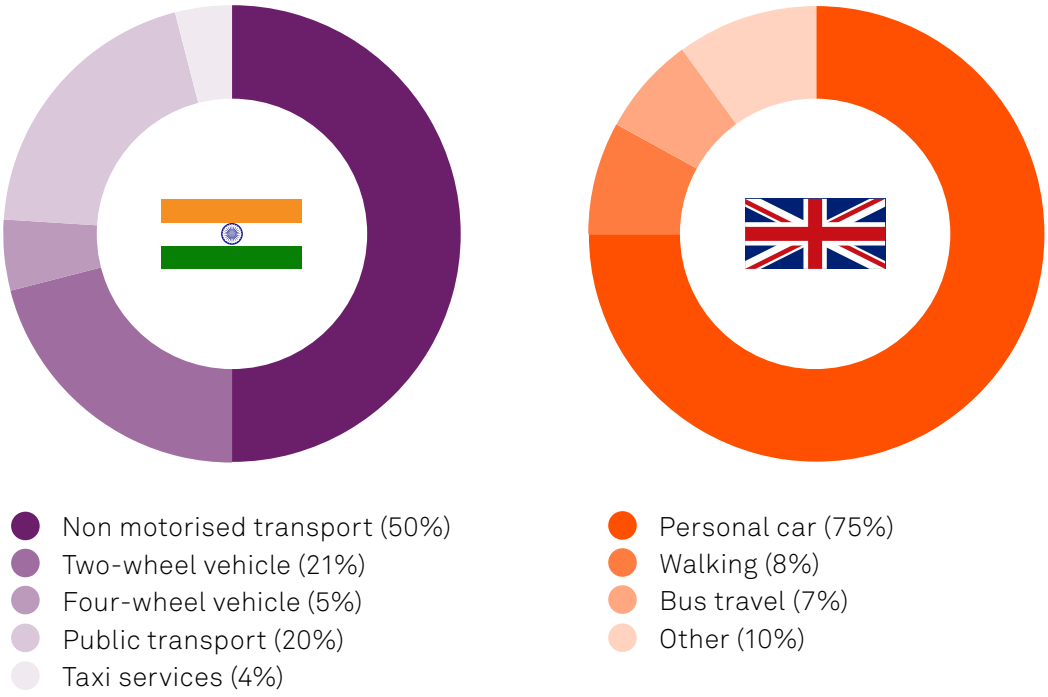


Figure 2 (left): Modal share for urban commuting trips in India (Census of India, 2011)[7,8]; Figure 3 (right): Modal share for ALL trips in England, UK (DfT 2018)[9]

Underdeveloped infrastructure for active travel is one crucial reason why the share of NMT in urban areas is predicted to decline across India - along with the status associated with owning a motorised vehicle[10]. While public transport represents a large modal share, there are numerous issues with the provision, a common one being that the supply has not caught up with the rapid population increase (and thus transport demand) seen in most major cities. Yet, Ola Mobility Institute (2018) found that as many as 80% of transport users would consider switching from their current transport mode to public transport, on the condition that its accessibility (e.g., access to

ii 75% of all trips undertaken by English residents are by car or van, however, van travel only amounts to a negligible 2% percent of car/van travel (Dft 2018).

stations, geographical coverage, frequency of service), affordability and comfort increased. They also observed that improved options for first- and last-mile travel would likely convince more people to use public transport[11].

The infrastructure for walking and cycling is generally inadequate in India, and many would likely opt for other ways of travelling if given the opportunity.

Socioeconomic and demographic factors influence modal choice. Not surprisingly, non-motorised travel is over-represented in the lowest income groups, while public transport tends to be used primarily by low- and middle-income groups. Personal cars are affordable only to a small portion of the population[12]. There are considerable differences between women and men's travel behaviour and preferences. When personal income increases, men are quick to shift from NMT or public transport to personal motorised transport (e.g., a two-wheeler). By contrast, women who can afford personal-use transport still tend to prefer public or shared transport services, as it is perceived as safer than travelling alone[iii][13]. Indeed, safety is a major influence on women's travel choices. Mahadevia and Advani (2016) note that Indian women commonly harbour a fear of violence and harassment when travelling by any mode and for any purpose. In addition, cultural expectations serve to shape women's travel behaviour[iv][14].

In terms of distance travelled, nationally, around 70% of work trips are shorter than five kilometres while about 10% extend beyond ten kilometres[15]. Gender and household income influence how far people will travel for work, where men and higher-income individuals tend to commute the furthest[v]. Reasons cited for this difference were that travelling long distances is associated with decreased safety and security among women. Another reason behind women's comparatively shorter trips is that they generally have more responsibility for informal household and child-rearing work, necessitating them to stay closer to home. In general, women make more non-work-related trips than men do, and their journeys more often involve several stops, serving multiple purposes[16]. As an example, a multi-stop, multi-purpose journey could involve going from home to pick up children from school, stopping at the market to pick up groceries, going past the pharmacy, visiting a relative to drop off medicine, and then returning home. Similar effects of the division of paid and unpaid labour on men and women's travel patterns are seen in large parts of the world, including India and the UK.

On a more general level, **current challenges for Indian travellers include time-related transport exclusion** (i.e., the inability to access required destination in a reasonable time), decreased affordability of travel, increased urban accident rates, and increased air pollution[17].

iii In one study, 92% of working women in India felt unsafe while travelling (Verma et al. 2017). When given a choice between using a sharing service or driving a two-wheeler, studies have found that women would, unlike men, opt to travel by taxi or rickshaw before using a personal two-wheeler vehicle (Baindur & Rao 2016; Mahadevia & Advani 2016).

iv In some Indian cultures, it would not, for example, be acceptable for a woman to travel in close proximity to men, meaning that these women's public transport options are limited to services that offer, for example, women-only carriages. Some traditional women's attire, such as sarees, may also not permit women to travel by some modes of transport, such as bicycles.

v Baindur & Rao (2016) observed that Bengalurean men would travel as far as 25-30km (one way) for employment while working women would not exceed a commuting distance of 10-12km. Further, Mahadevia and Advani's (2016) study of gender differences in travel behaviour among Rajkot residents highlights a divergence in travel distances and mode choice among women and men. Here too, women made fewer and shorter trips than men. The authors observe that trip length and frequency increased with higher income; however, the relationship was stronger for men than women.

4. Electric Vehicle Market Overview

4.1 Ecosystem

The EV ecosystem is complex. In this report we conceptualise the landscape by considering four elements - the charging infrastructure used by EVs, the users who travel or transport goods using the different options, the vehicles and their components and finally the electricity network which powers it all.

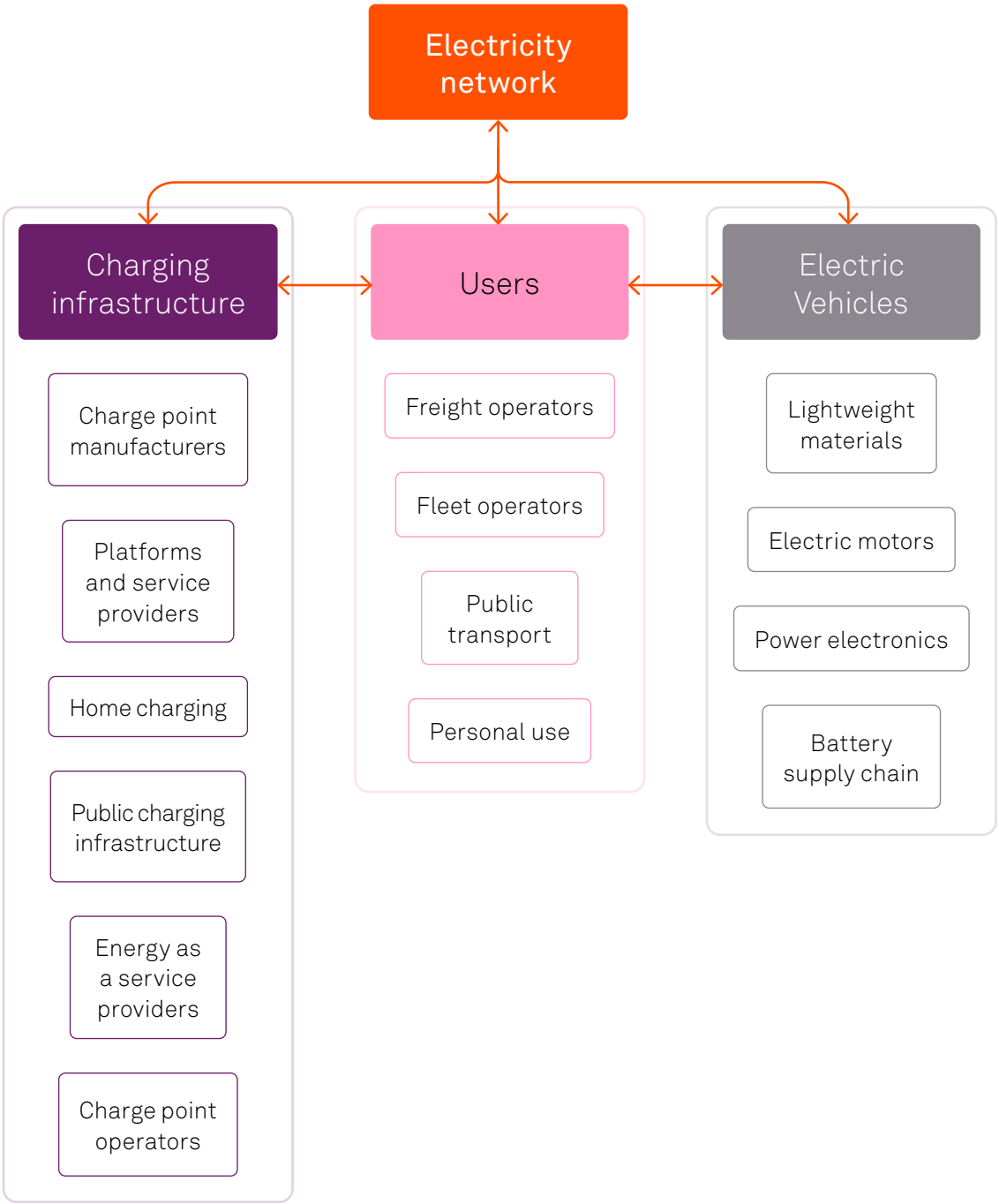


Figure 4 EV Ecosystem in India

4.2 Vehicles

Current Adoption

Electric Vehicles (EVs) account for less than 1% of total vehicle sales in India. However, as many as 90% of current four-wheeler owners would be willing to switch to an EV provided that the right infrastructure is in place[18], while 75% of the population believe EVs could replace ICE vehicles by 2030[19].

Given their economic viability, in terms of price and fuel economy, two-wheelers account for the largest share of the EV market at 62%, followed by three-wheelers at 37%.

	Two-wheelers	Three-wheelers	Passenger Vehicles
FY20	0.9% 152,000 units	14.1% 90,000 units	0.12% 3,400 units
FY19	0.6% 126,000 units	14.3% 100,000 units	0.11% 3,600 units

Figure 5 EV penetration in India by segment (Source: SMEV Publications, September 2020)

In the electric two-wheeler segment, electric motorcycles and scooters are popular modes, as like conventional two-wheelers they are easier to navigate through congested roads, as is often the case in India. These vehicles mostly have a removable battery, which can be charged from traditional wall sockets. COVID-19 disrupted the supply chain of electric two-wheelers for most of FY2020 but activity has gradually recovered over the last few months. The vast majority (97%) of vehicles sold in this segment are electric scooters, while motorcycles and e-bikes account for the remaining 3%.

From a speed point of view, low speed (up to 25 km/hr) and medium speed electric two-wheelers (up to 40 kmph) with conventional lead-acid batteries currently dominate the market. This is mainly because in terms of upfront cost, they are already on a par with ICE vehicles. However,

with more companies becoming eligible for FAME-II[vi] incentives in 2020, the market for high-speed models is expected to grow rapidly in the next two years.

In the three-wheelers segment, there are an estimated 14 electric three-wheelers for every 100 three-wheelers (penetration of 14%), representing the highest penetration of all segments. This estimate however doesn't include the sizeable e-rickshaw market with estimated annual sales of 0.7 million[20]. More than half of this market, however, is unregulated and dominated by several small players.

Electric four-wheelers have the lowest penetration rate of 0.12%, implying of the 2.77 million passenger vehicles sold in FY2020[21], only 3,400 were electric. This low traction is attributed to factors including high upfront costs and the lack of models in the market that qualify for government incentives (as discussed in Section 7.2).

The level of market maturity also varies by states depending on factors including demographics, income levels, regulatory landscape and urbanization. The state of Uttar Pradesh, for instance, with one of the lowest urbanisation rates has seen significant uptake of electric two-wheelers. Maharashtra, on the other hand, with a higher urbanisation rate, has the highest penetration of electric three-wheelers and passenger cars. Delhi is home to the largest electric commercial vehicle fleet due to a higher demand for electric buses and trucks. Figure 6 shows how the country's EV policy (FAME-I) drove EV sales in different states.

Image credit:
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vi The second phase of the national government's Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) scheme (April 2019-March 2022); discussed in detail in Section 7

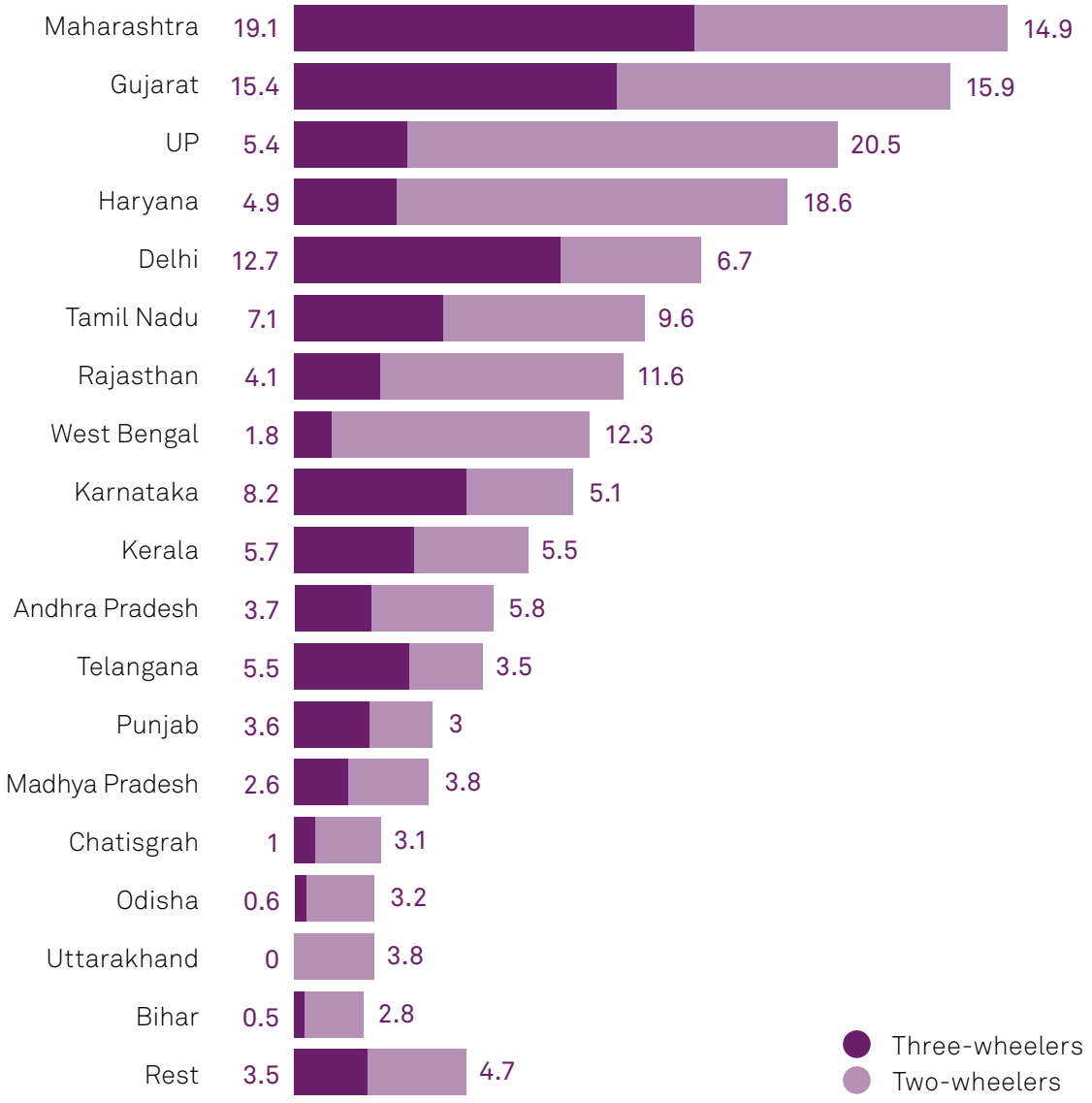


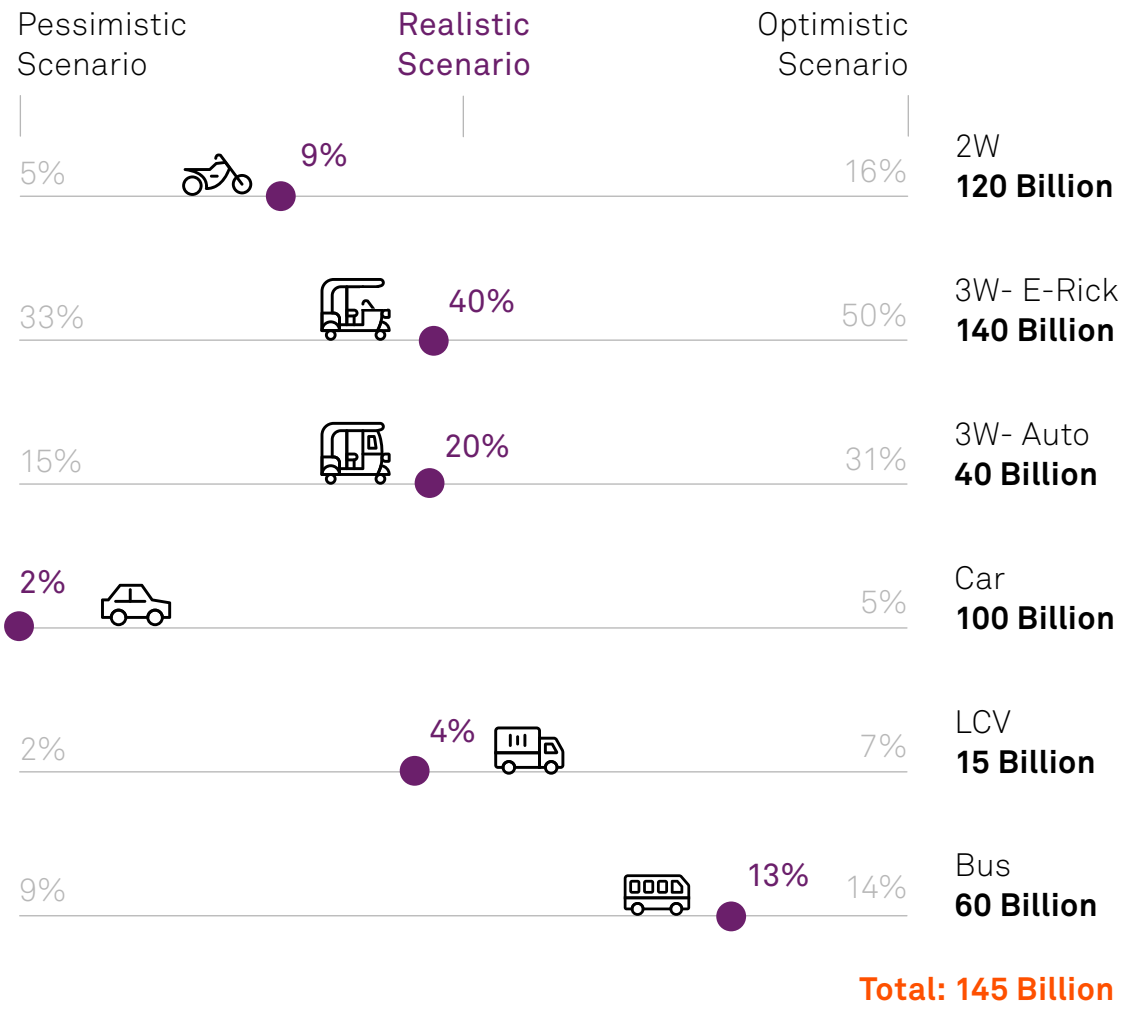
Figure 6 Number of Electric Vehicles Sold Under FAME-I (in thousands), 2018 (Note: Data for four-wheelers by state not available. Source: ElectricVehicles.in, 2018, accessed via Center for Strategic and International Studies (CSIS))

The Indian EV market can also segmented by city tiers. Tier-1 cities include the most developed cities with population over 1 million and entail higher living expenses. There are eight Tier-1 cities, namely, Ahmedabad, Bengaluru, Chennai, Delhi, Hyderabad, Kolkata, Mumbai and Pune. Another 97 cities fall under the Tier-2 category and the remaining fall under Tier-3[22]. For the EV sector, it is advisable to view the market by cities as around 50% of the world's electric vehicle sales are concentrated in 25 global cities[23].

Forecasts for Adoption

In a realistic scenario, the Indian market will likely be worth around £4.8 bn (INR 475 bn) by 2025 - driven mainly by the two- and three-wheeler segments[24]. With the right government policies, a local supply chain, lower battery prices and widespread charging infrastructure the market may be even larger (Figure 7). Specifically, as per Avendus Capital[25], an optimistic scenario would mean:

- Existing government EV policy expands to include mandated adoption targets
- Battery prices (a key cost factor in cost structure of EVs) fall below the 'tipping point' of US$120-130 per kWh
- Access to fast charging improves significantly
- More than 80% of EV supply chain becomes localised



*Penetration for e-rickshaws refers to adoption of Li-ion batteries in the segment.
Figure 7: EV Penetration (% of Total Vehicle Sales) Source: Avendus Capital, 2020

Electric two-wheelers

India is the second largest two-wheeler market globally with sales of 21 million units in 2019, second only to China[26]. Electric two-wheelers are gradually acquiring a growing share of this large market. In a realistic scenario, EV penetration in the two-wheeler segment is forecasted to increase from 5% currently to 9% by 2025[27]. A significant push in the segment is anticipated after 2024, when battery prices will likely move below US$100/ kWh[28]. This price point will in turn enable electric two-wheelers to reach price parity with ICE ones in terms of purchase price.

"In terms of TCO, electric two-wheelers are at parity with ICE for multiple scenarios. Depending upon the vehicle specification, TCO parity is achieved at different usage levels. Low/medium speed e-2W would achieve TCO parity at less than 10Km of daily usage. The TCO for high speed 2Ws is not yet attractive and TCO parity is achieved at 40+ Km daily usage. While the upfront cost (without subsidy) in the case of a medium–high performance electric 2W is 50-75% higher than the ICE equivalent, the operational cost per Km is almost 1/6th that of an ICE 2W."

Avendus Capital, July 2020

In an optimistic scenario, penetration is projected to reach 15% by 2025. This higher uptake will be driven by both demand and supply side dynamics. From the supply side, a larger range of models from a growing number of start-ups will mean better offerings positioned at attractive prices. Lower prices and better fuel economy will make them more commercially attractive than ICE vehicles, driving demand amongst both the consumer market as well as regional bike or scooter rental companies such as Vogo, Yulu and Bounce.

Across Indian states, Uttar Pradesh held the largest share of 15% of the electric two-wheelers market in 2019 and continues to see high demand for electric scooters and motorcycles, along with Delhi, Karnataka and Maharashtra [29]. This growing demand has sparked high investment from OEMs who have expanded their dealership networks in these states.

Competitive and funding landscape

The electric two-wheeler category has more than 20 manufacturers currently operating in the country. However, the top three players - Okinawa, Hero Electric and Ather - together account for roughly 75% of the market[30]. Notably, all major electric two-wheeler companies operating in India are Indian origin.

High-speed (>40km/h) models are seeing growing traction comprising over 60% of the 35 models launched between 2018 and 2020. Under the FAME-II scheme (discussed in Section 7), EVs with more than 50% of components manufactured locally qualify for subsidies. Okinawa and Ather have models which meet this criteria and as such have been able to offer products at lower prices

than competitors (or in the case of Ather, offer a premium product at a slightly reduced price) - policy here having the desired effect of both localising production and driving uptake.

Over the last two years, start-ups in the segment have raised more than $600 million in investment (list of major investments in appendices). The largest funding infusions are usually seen from consortiums of investment firms such as Westbridge Capital, Ant Financial, Astrend India Investment and Nexus Venture Partners. These investments have been used as upfront capital required in the initial stages of assembly and supply chain setup, as well as to keep the price of the EVs low for customers (JMK Research, 2020)[31].

The segment has also seen some international activity. For instance, in May 2020, Ola Electric Mobility acquired Amsterdam-based Etergo BV, manufacturer of electric scooters. Ola Electric also plans to develop the world's largest electric scooter factory in Tamil Nadu. Other leading firms such as Hero Electric, Ather Energy, Ampere, Okinawa, are also establishing manufacturing units throughout the country.

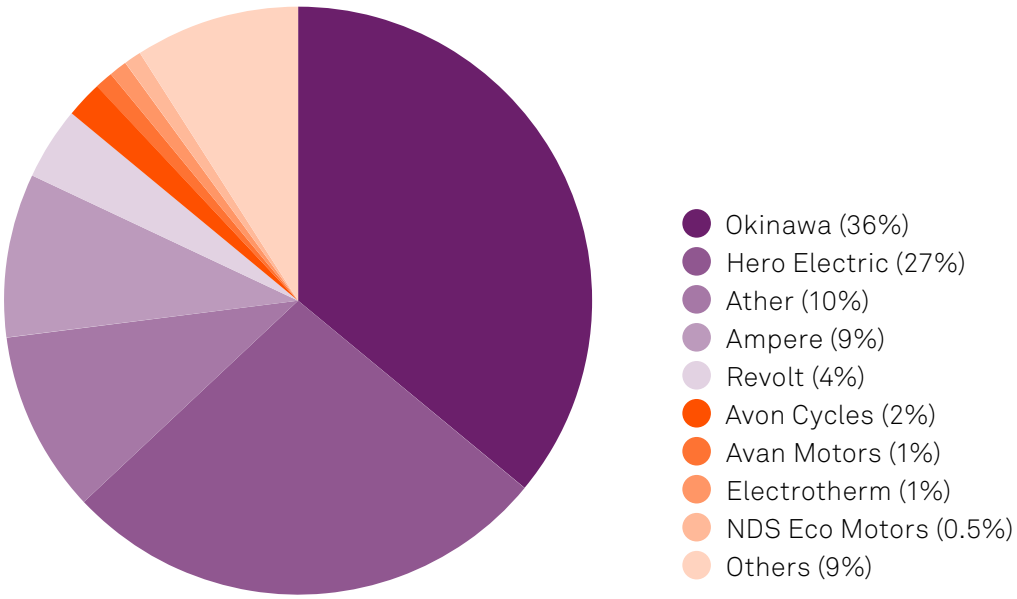


Figure 8 India: High speed electric (>25kmph) two-wheelers market share, FY 2020 (Source: Ministry of Road Transport & Highways (MoRTH), JMK Research)

OEMs	Category	Key Models	Price (£)	Advertised Range (Km)	Top Speed (Km/hr)
Hero Electric	E-scooter	Flash E2	500	65	25
	E-scooter	Optima E2	570	60	45
	E-scooter	Nyx ER	700	100	42
AMPERE	E-scooter	Zeal	700	70	50
	E-scooter	Reo -Li	450	55	25
	E-scooter	V-48	370	55	25
OKINAWA	E-scooter	I-Praise+	1090	160	60
	E-scooter	Lite	600	50	25
	E-scooter	Ridge+	730	100	55
ATHER	E-scooter	Ather 450X	1490	85	80
REVOLT	E-scooter	RE300	1180	80	65
	E-scooter	RE400	1380	85	80
BAJAJ	E-scooter	Chetak	1150	95	80
TVS	E-scooter	iQube	1150	75	78
BuymyEV	E-scooter	E3	550	15-25	25
	E-scooter	E5	not available	32	15-24
	E-scooter	X5+	not available	56	15-24
Greendzine Tech	E-moped	Quark U	not available	flexible	flexible
PUR Energy	E-scooter	EPluto 7G	800	120	60
Evolet	E-scooter	Evolet Polo	540	60-65	25
BattRE	E-scooter	Electric	635	90	
	E-scooter	LoEV	699	90	45
	E-scooter	IOT	800	85	25
Altigreen	E-scooter	AltiGreen E2W	not available	50	60
Tresmoto	E-scooter	Not launched yet	not available	90	75
GoZero Mobility	E-bikes	SKELLIG LITE	200	25	25
	E-bikes	SKELLIG PRO	400	70	25
	E-bikes	SKELLIG	325	45	25
	E-bikes	One		55-60	
AlphaVector	E-bikes	MERAKI BY NINETY ONE	300	35	25
Hero Lectro Kinza	E-bikes	Lectro Kinza 27T	290	25-40	25

Table 2 Examples of Models Offered by Key Market Players

For further reading on the two-wheeler EV segment in India, please read **here.**

Electric three-wheelers

Currently the dominant mode for last mile connectivity in several states including Delhi, Bihar, West Bengal and Uttar Pradesh, the three-wheeler market is expected to witness strong growth in currently under-penetrated states such as Raipur, Indore, Bhopal and Orissa in the upcoming years. This growth will primarily be driven by the low running costs of electric three-wheelers which offer savings of 70%-80% compared to the currently dominant gas-powered three-wheeler.

E-autos[vii] are forecast to reach a market size of £400 million by 2025 at a penetration of 20%[32].The e-rickshaws market, although highly fragmented and unregulated, is another significant market expected to reach 40% penetration by 2025 with a market size of £1.4 billion.

The market size of electric three-wheelers in India is already (as of 2019) 20% larger than that of conventional three-wheelers. But further growth potential lies in converting pedal rickshaw drivers present in abundance in northern and eastern India to electric three-wheelers.

Exports represent a significant opportunity for electric three-wheelers in India. Currently, exports account for roughly 50% of the total ICE three-wheelers manufactured in India[33]. Developing countries across Africa, Asia, Middle East and even Latin America comprise the major export markets for ICE three-wheelers. With electric counterparts growing in popularity in some of these markets, EV exports are likely to grow.

In terms of **battery technology** used for electric three-wheelers, lead-acid currently dominates the market due to lower costs, widespread availability and after-sales service stations. However, OEMs have started shifting towards safer, more durable but also more expensive Li-ion batteries. Regulatory-compliant, high quality e-ricks with Li-ion batteries are priced around £1900 (INR190,000). Comparable quality e-ricks with lead-acid batteries are priced around £1300 (INR 130,000). As per the International Centre for Automotive Technology (ICAT), 80%-90% of the newer models tested and certified are based on Li-ion batteries.

Furthermore, the current electric three-wheeler stock in India is largely comprised of low-speed vehicles. The high-speed market - currently at a nascent stage - is slowly seeing some traction especially in the goods delivery or cargo segment. With several state governments as well as e-commerce companies planning to convert existing auto fleets to electric, the market is expected to continue growing at a rapid rate. The **battery swapping model** (which is already popular in two-wheelers and discussed further in section 4.4) looks set to further accelerate growth in the segment.

vii There are several differences between e-rickshaws and e-autos. The main salient difference is that e-rickshaws, still unregulated, generally travel at a speed between 20 and 35 kmph. E-autos, more regulated, can travel at a maximum speed of 60-70 kmph

Competitive landscape

Over the last decade, the low-speed, electric three-wheeler market in India has grown rapidly with more than 600 registered market players currently in the segment[34]. However, this rapid growth is largely attributed to non-incorporated small suppliers, collectively known as the 'unorganised sector' in India[viii]. This unorganised sector accounts for roughly 60% of on-road e-rickshaws in the country and is characterised by significantly lower prices compared to organised players. However, with the growing push from government for ICAT-certified models from late 2018, the share of 'organised' players is gradually growing.

Mahindra Electric, Kinetic Green, Atul Auto, Lohia Auto, Piaggio, Gayam Motors, Clean Motion India, Transvahan, Terra Motors, Goenka Ecoyan, Saera Electric and Adapt Motors are some of the key players in the market. Of these, Terra Motors (Japanese) and Piaggio (Italian) are two international players that have acquired substantial market share through their Indian subsidiaries. Players like Altigreen and Volta are involved in retrofitting of conventional three-wheelers to electric.

Other than Atul Auto, market leaders from the conventional three-wheeler industry including Bajaj Auto and TVS are yet to launch their electric three-wheeler portfolio (expected to be launched in 2021). The entry of large players can potentially stimulate further demand in the market, providing the scale required for a financially viable supply chain.

OEM	HQ City	Key Models	Price (£)	Battery	Range (Km)	Top Speed (Km/hr)
Mahindra Electric	Bengaluru	Treo Treo Yaari Treo Zor	2700 1700 2730	Lithium Lithium Lithium	130 100 125	45 25 50
Kinetic Green	Pune	Kinetic DX Kinetic Safar Smart Kinetic Safar Shakti Kinetic Safar Jumbo	1400 1900 1500 2500	Lead-acid Lithium Lithium Lithium	60 60 60 120	25 25 25 55
Lohia Auto	Gurugram	Comfort DLX Hamrahi	1400 1300	Lead-acid Lead-acid	100 75	25 25
Piaggio Vehicles Pvt. Ltd.	Pune	Ape E-City	2000	Lithium	80	60
Terra Motors India Pvt. Ltd.	Gurugram	Y4 Alfa	1200	Lithium	100	25
Gayam Motor Works (GMW)	Hyderabad	Urban ET	3250	Lithium	110	55
Atul Auto	Rajkot	Elite Cargo	1650	Lead-acid	80	25

Table 3 Product Range of Top Market Players (Cargo and Passenger)

viii The unorganised e-rickshaw sector has evolved rapidly in India particularly in West Bengal, Bihar and Delhi.

Electric four-wheelers

The four-wheeler segment currently has the lowest EV penetration of 0.12% but is projected to grow to 5% by 2025[35] or 10%-15% by 2030 based on projections by KPMG and CII[36]. The demand in the short to medium term will largely be driven by commercial fleets - including taxi and goods delivery services. For the commercial fleet segment, penetration is forecast to range between 20%-30%[37].

This variation between personal use and fleet use segments can be explained by the Total Cost of Ownership (TCO) for the two use segments. Fleet operators benefit from lower TCO on account of high utilisation of their vehicles - EVs offer lower TCO for average daily mileage over 120km[38]. Fleets also have the advantage of being able to invest in their own charging infrastructure. Fleet owners and operators such as Lithium Urban Technologies, eee-Taxi and Zoomcar operating in Tier-1 cities in India are demonstrating the successful transition to EVs for commercial purposes.

Factors such as limited market offerings, high upfront costs, insufficient battery life, high dependency on imports, low range, power outages and crucially, an underdeveloped charging ecosystem continue to hold back the adoption of four-wheeler by consumers. There are around 26 EVs per installed charger in India, compared to only 8 in China and 17 in the US (Avendus Capital, 2020). For fast chargers, this number goes up to 340 EVs in India (15 for China and 122 for the US). However, in cities such as Bengaluru, charging infrastructure has improved significantly over the last two years. Bengaluru's electricity provider Bescom, for instance, has installed fast-charging infrastructure in 12 locations across the city. EV manufacturers too are offering emergency charging for their customers for intra-city trips.

Competitive Landscape

The electric four-wheeler market is currently limited to only four market players (see Table 4 below) but several new players, domestic and international, are planning to launch electric passenger cars over 2021-22. Two of the OEMs - Hyundai and MG Motor - currently import their EVs to India as CBUs or SKD units. In contrast, Tata Motors and Mahindra Electric manufacture locally, saving on customs duty, and are therefore able to offer their EVs at lower prices[39].

However, a mix of factors, including the supply chain disruption caused by Covid-19, have discouraged some players from launching new models in 2021. For instance, Maruti Suzuki's plan to launch Wagon R EV - the electric model of the popular ICE model - has been reportedly scrapped on account of 'commercial viability' issues[40]. Some sources suggest that these issues relate to higher costs of component imports and challenges related to supply chain localisation. Several other EV models in the segment including the Altroz EV and Hornbill EV from Tata Motors, Mahindra's eXUV300 and the Renault Kwid EV[ix] are all set to be delayed by over a year. Notably, most of these planned launches fall in the 'affordable' category of under INR 10 Lakhs (£10,000) - the category expected by OEMs to see the highest demand in the near future.

Global EV company Tesla recently set up a subsidiary in India and plans to establish its manufacturing unit in the state of Karnataka (also home to other automotive OEMs e.g. Toyota). The company plans to use the manufacturing base in India to cater to its exports market [41].

ix The 'affordable' model customised for emerging countries has been designed in India but is currently manufactured and sold in China.

OEM	Key Models	On-road Price[x] (£)	Battery Type	Range[xi] (km)	Top Speed (Km/hr)	Key Highlights
Tata Motors	Tigor EV Nexon EV	10,000 14,695	Li Li	140 300	80 120	Launched in Oct 2019; Launched in Jan 2020; Highest selling electric car in March 2020
Mahindra Electric	E-Verito D2 (Base Model)	10660	Li	140	86	Oldest EV player in India, having started its EV journey with Reva in 2001. Planning to launch e-KUV100
Hyundai	Kona Premium	27,700	Li	450	155	Launched in Aug 2019
MG Motor	ZS EV Excite	21,840	Li	340	140	MG received ~3,000 bookings for ZS in the first month of launch - more than cumulative electric car sales in 9 months prior to that

Table 4 Current market players in the electric four-wheeler segment (Source: Cardekho.com; Avendus Capital, 2020)

4.3 Vehicle Fleets

Vehicle fleets form a large proportion of cars in India; McKinsey has forecast that in 2025 around 17% of new car sales in India will be made to fleet owners[42].

Types of fleets in India include:

- **Private Hire/Self-drive Rentals**: Market expected to double in size by 2025 (McKinsey, 2020), mainly led by the two-wheeler category. Current two-wheeler fleet size (electric and ICE) for this use case is estimated at 40,000-60,000 vehicles[43]. Electric four-wheelers are likely to see growing adoption for self-drive rentals or private hire, as Indian mobility providers, such as Lithium Urban Technologies, eee-Taxi and Zoomcar, look for new business models using their existing electric four-wheeler fleets[44].

- **Taxi fleets and ride-hailing platform fleets (such as Uber and Ola)**: Predicted to grow by 40 to 50% (McKinsey, 2020)[45]. Uber announced in Feb 2020 that it planned to more than quadruple its EV fleet in India by the end of the year from 350 EVs in Feb to 1500 by year-end.

x On-road Price is the final price payable by the customer to the Car dealer. It includes expenses including State Registration charges, Life-time Road Tax Payment, insurance etc. (Figures have been rounded-off)

xi As reported on companies' websites. Some companies report ARAI range while some companies report range under ideal operating conditions. The practical range however is lower than ARAI and lower than ideal range depending upon usage patterns.

Uber is continuing to partner with auto industry and start-ups to launch new electric mobility solutions. It has also run EV trials with Sun Mobility in the city of Chandigarh and plans to expand into two- and three-wheelers in 2021[46]. Another ride-hailing company Blu Smart Mobility launched a pilot program in June 2019, offering a 100% electric ride-hailing service in Delhi and Mumbai. The pilot concluded in Jan 2020 and they are now in the process of scaling the EV deployment across the country. This includes not only expanded its fleet but also the supporting charging infrastructure[47].

- **Fleets owned by corporates for employee transport**: A lack of sufficient public transport in urban environments in India means several large companies (such as Google, American Express, Accenture and EY) offer transport services to their employees. As of 2017 the employee transport sector in India accounted for approximately 23% of the national taxi market[48]. Companies offering EV fleets for employee transport have started to emerge. These include EEE Taxi and Lithium. Both the companies have been engaged in the IfCA program and are in the process of expanding their offering and charging infrastructure in India.

- **Urban freight distribution**: Several large companies and delivery platforms have already initiated trials with EV-based deliveries. For example, IKEA plans to transition to 60% of its home delivery fleet to be electric by 2021[49]. Food delivery company Swiggy has plans to pilot the use of EVs in 10 Indian cities, while major e-commerce player Flipkart too plans to electrify 40% of its delivery fleet[50].

The Energy and Resources Institute (TERI), an Indian policy research institute, published a roadmap on electrification of urban freight in India, capturing Indian and global best practices, current scenario in the India, and benefits of electrification of urban freight sector in the country.

Deliver Electric Delhi. Pilot project by Delhi government for freight vehicles in which 1,000 EVs will be used for deliveries over a year in partnership with 30 companies. Participants include-commerce companies Flipkart, Amazon, BigBasket, Grofers, Uber Eats and Zomato, logistics company such as Blue Dart Express, and EV OEMs including Hero Electric, Mahindra Electric and Tata Motors.

4.4 Vehicle Components and Manufacturing

Component	Cells / Batteries	BMS and BOP[xii]	Motor	Power Electronics	Chassis & Body
Market Size (£ million, 2025F)	800	350	250	350	750
Current Localisation	None	Low	Very Low	Very Low	High

Table 5 India: Market Size for EV components

The Indian EV components market will be worth approximately £2bn by FY25[51]. Currently most components are imported but several large OEMs including Maruti Suzuki are looking to manufacture locally, encouraged by the government's 'Make in India' and Phased Manufacturing Program (discussed in Section 8) and also to hedge against supply-chain disruptions in China (e.g. those caused by Covid-19 recently). For example, Tata AutoComp Systems, the auto-components arm of Tata Group signed a JV with Beijing-based Prestolite Electric in 2020 to enter the EV components market.

Given its size and growth potential, the three-wheeler components market is likely to be the most attractive. The use of electric powertrain in EVs instead of ICE also means a simplified manufacturing process which reduces barriers to entry.

A lack of R&D investment by Indian auto component manufacturers has created a huge gap in demand and supply for critical EV components including battery, motor controller and regenerative braking[xiii].

However, the localisation trend will play out differently for different components:

- **BMS and BOPs** are relatively easy to localise but require field experience for fine-tuning - companies seeking to enter this market will therefore need to conduct trials and refine their products before scaling production and formally launching.
- **Power electronics including EV controllers** especially for the two- and three-wheeler segments are seeing significant interest from local players, especially as global players are largely focused on four-wheelers. Controllers are technology intensive and can be developed locally but require heavy investments.

xii Battery Management Systems (BMS); Balance of Pack (BOP) form two of the three components of a battery pack (third being Cells)

xiii An integrated vehicle braking system which provides for the conversion of vehicle kinetic energy into electrical energy during braking.

- The **domestic motor industry** is currently hindered by the lack of rare earth magnets, a primary component of electric motors[xiv]. Although efforts, such as by Toyota[52], are being made to reduce the use of rare earth magnets in EV manufacturing, they are still a long way from commercialisation.
    - While smaller motors for two- and three-wheelers will likely be localised in the near term, larger motors needed for four wheelers will need to be imported until local demand and manufacturing for four-wheelers gain more scale.
- **Cells / batteries,** the costliest component of EVs, are the most challenging to transition to local manufacturing and in the short to medium term, most are expected to continue being imported.

The growth of the EV sector in India naturally means that the demand for batteries is accelerating. Table 6 shows battery production requirements, under two different scenarios, to cover domestic demand.

The India Energy Storage Alliance (IESA) forecasts that the EV battery market in India will be grow at a CAGR of 32% over 2020-2027 to reach a demand of 50 GWh. 80% of demand is expected be for superior quality lithium-ion batteries. In terms of value, this translates to a market of $580 million (£425 million) by 2027[53].

	2025	2030
Conservative Scenario	50 GWh	110 GWh
Base Scenario	80 GWh	230 GWh

Table 6 EV battery demand in India (from Bloomberg NEF, RMI Analysis, accessed via NITI Aayog)

Currently lead acid-based batteries account for over 75% of EV battery sales for two- and three-wheelers. However, OEMs have started shifting towards lithium-ion batteries in part to meet government's 'advanced battery' criteria to access FAME-II incentives (Section 7.2). Li-ion batteries exhibit better performance than lead-acid batteries and are becoming more price-competitive. As per ICAT & ARAI, 50-70% of the newer models tested and certified are based on li-ion batteries.

OEMS are using a range of business models (figure 9) to source battery packs; either through integrating part or the whole of battery manufacturing into their business or by working closely with suppliers. As is seen elsewhere in the world, battery cell and pack manufacturing facilities are being constructed close to existing vehicle manufacturing facilities.

xiv Magnets are a primary component in electric motors. A motor operates when a coil of wire, encircled by strong magnets, spins. Over 80% of electric cars sold globally utilized permanent magnet-based motors in 2019. These magnets are typically made with rare-earth materials such as neodymium and dysprosium, which are significantly stronger than other types such as ferrite or alnico magnets.

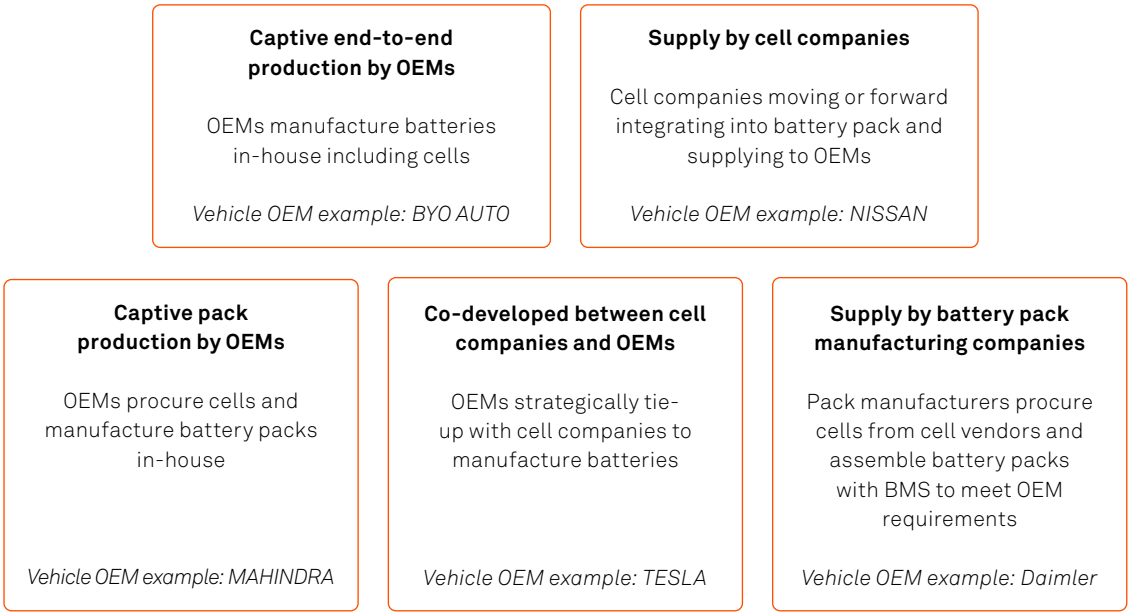


Figure 9: Five key battery sourcing strategies adopted by OEMs (Source: Avendus Capital, 2020)

In terms of battery size, the Indian market is dominated by small batteries in the range of 1-10 kWh which are suitable for the two- and three-wheelers. Furthermore, even locally manufactured passenger vehicles operate with very small batteries of <30 kWh (globally, the average battery pack energy is 60 kWh).

When batteries reach the end of their serviceable life for EVs, they are often currently just dumped in landfill sites[54], with negative environmental consequences. This is changing however with Delhi adopting after-use EV battery recycling in their state level policy and the firm Tata Chemicals commissioning a li-ion battery recycling plant in Maharashtra in 2019. Another use for batteries that no longer meet automotive specifications would be to support the grid as it integrates a larger share of intermittent renewable generation.

Competitive Landscape

Even though most Li-ion battery packs are imported from China, a local supply chain is starting to form. Avendus Capital estimates that the current battery manufacturing capacity in India is around 2GWh. Establishing their own battery pack design and assembly would offer benefits to vehicle OEMs, as vehicle performance can be improved through tailor made battery designs and BMS. Some examples of recent partnerships aiming to develop a local supply chain include:

- Suzuki Motor Corporation has partnered with Toshiba and Denso to develop a Li-ion battery manufacturing facility in Gujarat. The investment is estimated to be INR 11.5 billion (£115 million).

- Exide Industries Ltd and Amara Raja Batteries Ltd have formed JVs with foreign companies to start assembling batteries.

- Mahindra and Mahindra (M&M), a part of the US$19 billion Mahindra Group, is collaborating with South Korea's car battery specialist LG Chem (and Japan's Toshiba) to supply unique lithium-ion battery cells exclusively for India
    - As part of the deal, LG Chem will supply lithium-ion cells based on chemical elements of nickel, manganese, and cobalt that will be deployed in the EVs manufactured by Mahindra and its South Korean unit SsangYong Motor.
- Indian Oil Corporation Ltd announced its plans to partner with a foreign start-up to establish a 1 GW battery manufacturing plant in India.

India allows a number of partnership and market entry structures for foreign companies, as listed here.

Currently leading battery pack suppliers in India include Exicom, Bosch, Tata Autocomponents, Phylion, Exide-Leclanche, Greenfuel and Okaya. Startups such as ChargeDock, Euclion and Octillion are doing battery pack assembly at a small scale in various regions in India. Larger companies like RIL, Adani, BHEL, IOCL, Panasonic and Tata Chemicals have indicated potential interest in local battery cell manufacturing.

Manufacturers
Total installed capacity: ~2 GWh

Domestic companies

EXICOM POWER SOLUTIONS
AMARA RAJA
EXIDE
OKAYA
TATA
GREENFUEL
SUN MOBILITY

Global companies

国轩高科 GUOXUAN HIGH TECH
LG Chem
PHYLION

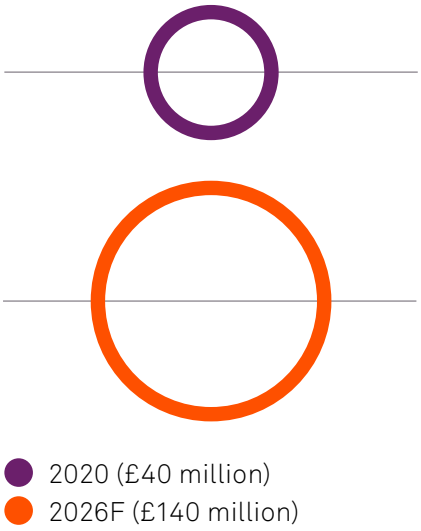
OEMs

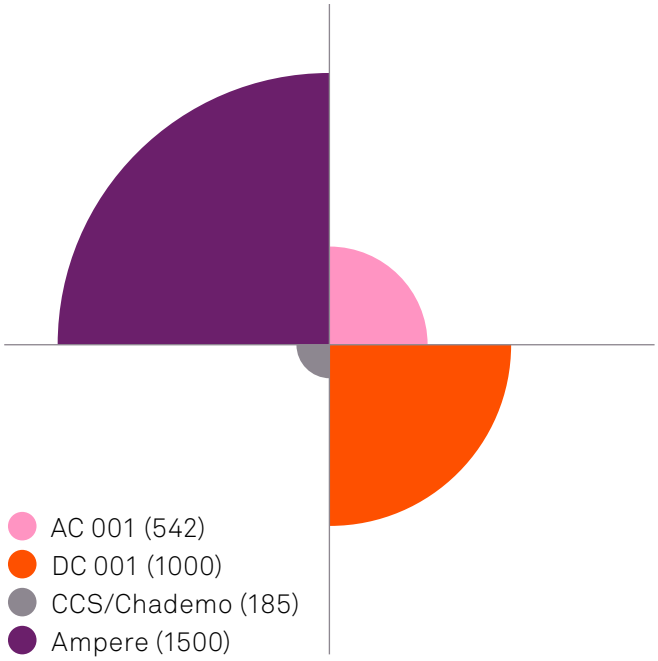
BYD
Mahindra
ATHER

Figure 10: Illustrative List of Battery Manufacturers in India, 2020

4.5 Charging infrastructure

Charging infrastructure in India is currently quite under-developed with as many as 26 EVs per charger available in the country, compared to only 8 in China and 17 in the US (Avendus Capital, 2020). The public charging infrastructure market will grow at a fast pace over the next few years from £40 million in 2020 to £140 million by 2026. In 2019, sales of DC and Type 2 AC chargers overtook the sales of AC 001 chargers, indicating that faster charging is preferred by consumers (more information on charger types available in India can be found in section 8.1.1).





(Left) Figure 11 India: Public Charging Infrastructure Market (£million)
(Right) Figure 12 India: EV Charger Unit Sales, FY 2019 (Source: Indian Energy Storage Alliance)

Analysis by IESA suggests two-wheelers will largely depend on 'on-board' chargers of 400-700W in the short term. Two-wheeler fleets will encourage installation of more DC chargers of 1-2kW. Based on their operating patterns and daily mileage three-wheelers could also rely on public charging infrastructure for top-up charging during the day. Personal use four-wheelers, on the other hand, are expected mainly to be charged at home and workplace and to a smaller degree through public charging infrastructure.

Although for private use vehicles of all segments, home charging will be preferred and it is a major benefit offered by electric-drive technologies, it will not fulfil every charging need. Furthermore, a large number of houses don't have access to off-street parking; the lack of home charging solutions for apartment blocks, gated communities with shared parking facilities and houses without access to off-street parking will influence the development of reliable and accessible public charging infrastructure in driving further adoption of EVs (especially four-wheelers) for private use.

As well as off-street parking availability, EV users have also experienced problems with domestic

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charging driven by the voltage profile of the LV network at peak usage (voltage drops and losses of power). An unreliable LV network can make home charging challenging, even when off-street parking is available, and discourage uptake.

Fleet use four-wheelers will also generate significant demand for public charging infrastructure of DC15kW to 50kW chargers. Furthermore, anticipated growth in the sales of electric buses and luxury four-wheelers would in turn generate higher demand for CCS/Chademo chargers.

New business models have emerged including battery swapping and end-to-end charging solutions provided by OEMs. In June 2020, for instance, MG Motor partnered with Tata Power to install superfast chargers at select MG dealerships, while Lithium Urban Technologies, an EV mobility services provider, partnered with renewable energy solutions provider, Fourth Partner Energy, to build solar powered charging hubs across the country.

Battery Swapping

Battery swapping is gaining increased market traction especially in the two- and three-wheeler segments that need smaller, light weight battery packs. Estimates suggest the **EV battery swapping market in India will grow to $6.1 million by 2030, registering 31% growth during 2020-2030** (ResearchAndMarkets, 2020)[55]. This includes swappable battery packs offered through pay-per-use model or subscription models. Recently, the Indian government allowed the sale of electric two and three wheelers without batteries; batteries can be provided separately. Swapping stations can be either large installations that integrate battery charging with renewable generation or smaller sized stations that serve a smaller number of vehicles. Integrating battery swapping stations with onsite renewable generation or taking advantage of the available stored electricity to provide services to the network in the future might be another

income stream for battery swapping station owners.

For EV users, the battery swapping model tackles the key concerns over range anxiety, long charging time[xv], high upfront cost and battery reliability concerns. Generally, battery packs constitute 40-60% of the value of an EV. In the battery swapping model, battery packs are often separate from the vehicle and owned by battery suppliers. Therefore, EV owners only need to pay when they swap a used battery with a charged one (a rental model). To tackle the issue of battery weight that can hinder adoption in the car market, and therefore address two-, three- and four- wheelers, Sun Mobility offers a modular product. The number of battery packs used will change based on the vehicle type with larger vehicles requiring more battery modules that can still be swapped easily by the user.

However, for battery swapping to work most effectively, operators need to standardize batteries and operate in a closed loop environment. EV manufacturers are now creating an ecosystem of swappable battery stations in association with service providers.

This article by venture capital firm Aster Capital provides some interesting insights on the battery swapping model in India.

Public charging infrastructure

As well as the pull from the market, central Government policies will push for the development of a network of public charge points. In Jan 2020, the Government approved 2,600 charging stations to be set up under FAME-II. At state level ESCOMs are also encouraging deployment. Karnataka is aiming

Image credit:
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xv For instance, it usually takes about 6-8 hours for an electric three-wheeler to get sufficient charge to drive 35–45 miles.

to develop a network of rapid charging infrastructure on motorways to encourage uptake and serve interstate travelling under its Electric Vehicle and Energy Storage Policy. BESCOM is creating an urban charging network; to date they have rolled out a number of manned charging posts at government sites, a good first step that can be built upon by public and private players. However, the bidding and approval process for installing charging stations is lengthy and complicated.

In parallel to the development of a public charging infrastructure, fleet operators are investing in private charging networks. Currently, all players developing infrastructure for captive usage are also treating it as a business differentiator and not sharing it for public use.

Competitive Landscape

The Indian EV charging market is competitive, with more than 30 companies active in the charger manufacturing space. Currently, Exicom is the market leader with 1,500 installations across 13 states followed by Delta, and Okaya (IESA, 2020). Many of these companies, such as Siemens, Delta Electronics and ABB, are multinationals and have significant experience in power electronic products.

Smaller companies such as SunMobility, OLA Electric, Lithion Power, Amararaja and Bounce are focusing on installing the battery swapping infrastructure.

Major OEMs	Charger Type	EVs supported
Delta Electronics Masstech Controls Exicom Magenta Power Ather EvTeQ	Low Power EV Charger Bharat AC001 3.3kW	2W, 3W, 4W
ABB Delta Electronics Masstech Controls Exicom	Medium Power EV Charger Type 2 AC Charger 7kW to 22kW	2W, 3W, 4W
Okaya Delta Electronics Masstech Controls Exicom RRT Power Systems	Medium Power EV Charger Bharat EV DC Charger (BEV DC001) 15kW	2W, 3W, 4W,
ABB Delta Electronics Masstech Controls Exicom Tritium	High Power Fast DC Charger CCS/Chademo >50 kW	4W

Table 7 Major EV Charger OEMs in India by Charger Type

Installation of public charging stations is being led by state-owned companies such as electricity distribution companies BHEL, Tata Power, EESL, and electrical equipment supplier REIL.

In September 2020, REIL won a government contract to install 1,000 of the roughly 2,700 charging stations outlaid in the FAME-II policy. In turn, REIL invited expressions of interest (EOI) from companies to install the charging infrastructure in more than 75 cities. The scope of work includes site selection, development, operation and maintenance of interoperable electric chargers and associated infrastructure for all types of EV. The EOI requires bidders "to be registered in India; have experience in the automotive sector, e-mobility or EV charging infrastructure sector and over INR100 crore (£10 million) to invest in charging stations."

(PV Magazine, 2020).

4.6 Energy system

India is taking action to reduce its emissions in accordance with the Paris climate agreement. The Nationally Determined Contribution (NDCs) include the following targets:

- Reduce emissions intensity per unit GDP by 33% to 35% below 2005 values by 2030
- Increase non-fossil-based energy share to 40% of electricity capacity by 2030
- Increase carbon sink of 2.5-3 $GtCO_{2e}$ through forest and tree cover by 2030

Targets have also been set to tackle air pollution in cities by moving to zero tailpipe emission vehicles. Electricity generation today is primarily based on fossil fuels, but the share of renewable energy provided to the network is growing.

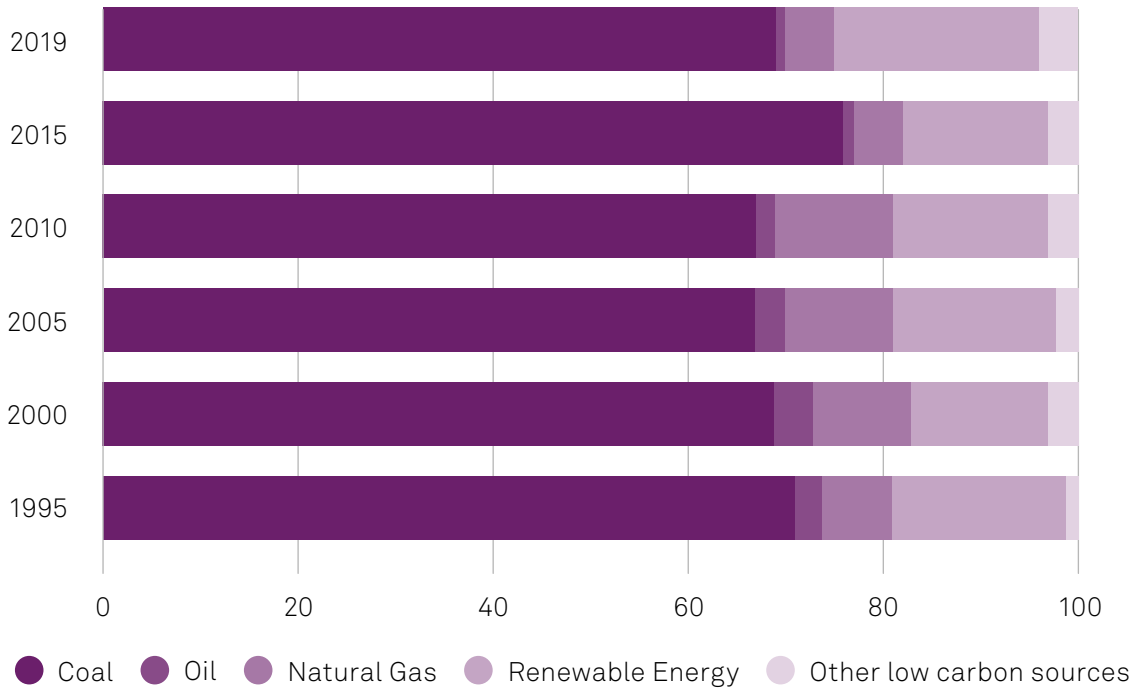

Figure 13 Share of renewables, low-carbon sources and fossil fuels in power generation in India (Source: International Energy Agency, 2020)

It is important to explore how the mobility sector can move to zero well-to-wheel emissions and take advantage of increased renewable energy generation.

Accessing flexibility in energy resources is seen as a key opportunity to facilitating the low carbon energy system of the future. This is driven by the need to accommodate intermittent, renewable technologies into the carbon mix, and to avoid creating unmanageable energy flows at peak times. The flexibility offered by vehicle charging can be harnessed through smart charging and can lead to cost reductions at consumer and system level.

Currently provisions such as network visibility, electricity market arrangements and an ability to send price signals and therefore incentivise consumers to respond to those are not present in the Indian electricity system. Accessing flexibility is a longer-term target for India and can emerge when the right infrastructure, communication and market arrangements are in place.

5. Selected Market Opportunities

India's growing EV industry offers a range of potential opportunities for UK firms. NITI Aayog (the Indian government's policy think-tank) has highlighted an India-UK partnership as key to capitalising on the EV expansion, emphasising that the door is open for UK businesses.

In this section we provide a high-level view of opportunities in the following areas:

- Vehicles
- Battery supply chain
- Charging infrastructure
- Electricity system

5.1 Electric Vehicles

Components and Manufacturing

The Advanced Propulsion Centre in its report "Strategic UK opportunities in passenger car electrification" highlighted 12 areas where the UK is well placed to become part of the global supply chain for EV components[56]. These were across three main areas: batteries, electric machines and power electronics. Some areas where the UK is well placed in the EV component supply chain can be seen below.

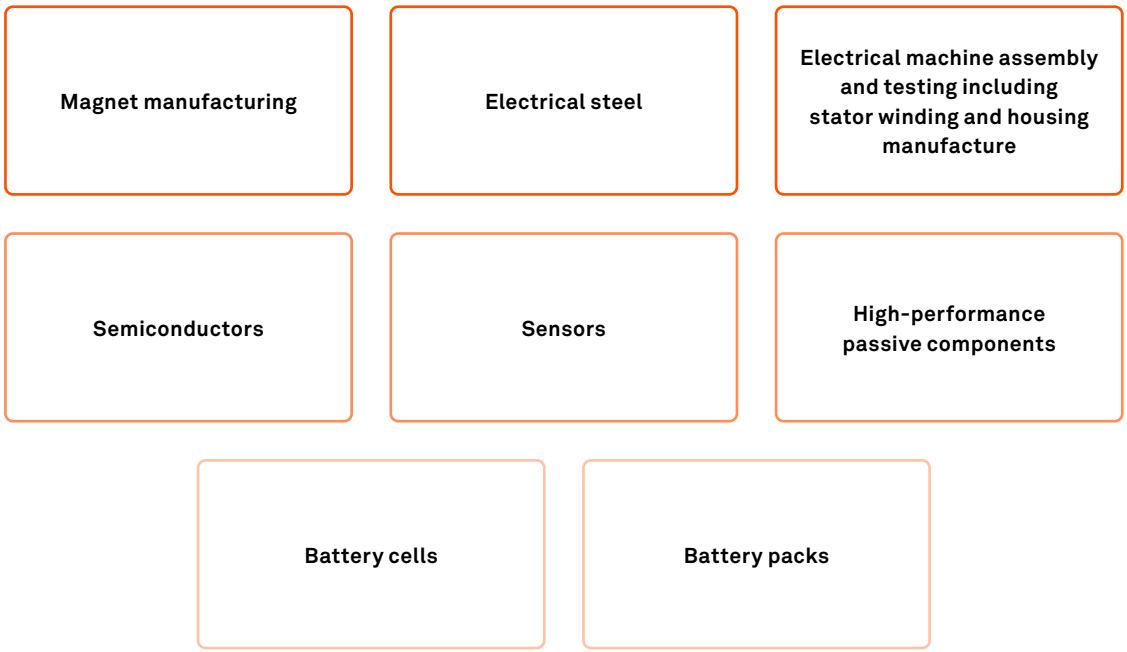

Figure 14 EV component supply chain, Areas of UK expertise

While these are areas of UK strength, as we saw earlier, India is focused on building domestic capacity in the EV supply base both for the manufacture of batteries and EV components. Recent increases in customs duty for EV components (Table 14) as well as the Phased Manufacturing Programme (PMP) that requires EV OEMs to use EV components manufactured locally to access

government subsidies mean UK companies interested in this space will have to either:

- Set up manufacturing facilities in India (as wholly-owned subsidiaries or in partnership/Joint Venture with an Indian company), as UK company GoZero Mobility has done (see case study in section 9). For example, there is IP and expertise in the manufacture of thin silicon-based electrical steel in the UK which might benefit from lower production costs in India.

- Offer design and consultancy services for vehicles and components to Indian OEMs.

- Export specific components and technology solutions to Indian partners.

In terms of batteries, the Indian government is making a concerted effort to ramp up domestic battery production with a range of incentives (amounting to around $4.6 billion) available to manufacturers that produce locally. These incentives are expected to be *performance linked* (considering energy density and cycle life i.e. the number of times the battery can be charged and discharged while retaining reasonable storage capacity) and ***technology agnostic*** - creating an exciting opportunity for innovative solutions. The National Mission on Transformative Mobility and Battery Storage outlined a five-year phased PMP until 2024 for large-scale, integrated batteries and cell-manufacturing gigafactories in India. As part of this, the government is planning to issue tenders inviting companies to set up a 50-GW battery manufacturing base in India. The program is expected to cover capabilities along the entire battery manufacturing value chain including raw material, cathode, separator, electrolyte, anode, cell and pack manufacturing.

Although customs duty and localisation requirements (to access FAME-II incentives) have made direct exports of battery packs financially less viable, there are still opportunities for UK companies to enter the Indian EV components segment. From component manufacturing to cell and battery pack assembly and innovative manufacturing methods the UK has IP, a strong R&D base and manufacturing capability that can be harnessed to address opportunities and:

- Form joint ventures or other arrangements to scale local manufacturing of Li-ion and newer variants such as sodium-ion batteries (some examples of such partnerships can be found in Section 4.4 under Competitive Landscape).

- Offer customised battery and cell design solutions to meet the specific needs of the Indian market which tend to require different battery size and energy ratings as discussed in section 5.2.

Develop BMS that optimise usage for local conditions (for example driving style and weather conditions), as American thermal management solutions firm Latent Heat Solutions (LHS) have done (see case study in section 9).

EV Fleets and Urban Freight

As noted in the market overview section 4.3, fleet operators (for passengers and freight) are leading the way in EV adoption in India due to the attractive TCO as compared to ICE vehicles. However, the management of an EV fleet is a different proposition to a traditional fleet and as such these companies may be interested in:

- Consultancy services to help them develop the best operational model.

- Fleet management software dedicated to EVs.
- Planning tools to help them identify the optimal locations for charge points.
- Tools to locate public or other charge-points (for operators who aren't planning on installing their own) and plan routes.

EV users

As EV uptake spreads beyond fleets to consumers, a range of additional service / solution opportunities emerges:

- Software solutions to provide accurate, real-time and context-sensitive (e.g., taking into account weather conditions) information to the user about vehicle available range and battery health during journeys.
- Software/platforms to facilitate journey planning. For example, route optimisation based on charging needs.

These products could be offered as standalone products or integrated with the vehicle itself, as seen in Ather's product. As with other opportunities partnerships with local manufacturers could be the route to market for UK companies.

5.2 Charging Infrastructure

The charging infrastructure sector offers multiple opportunities for international players. Mass market adoption of EVs will require coordinated actions between stakeholders (for example, vehicle suppliers, charge point operators, ESCOMs) and a charging infrastructure that is affordable, accessible and serves all consumer groups.

Solutions, both software and hardware that will improve power quality and therefore the home charging experience for consumers, are needed. Charging at off-peak times, coupling EV charging with periods of high renewable energy generation or with home PV systems could improve the experience and provide green electricity for home charging. Efforts towards product standardisation are progressing; this will enable interoperability but will also unlock the market for new charge point manufacturers.

Two-wheeler vehicle OEMs, such as BuymyEV and Ather Energy, are providing packages to their customers that include the vehicle and the home charge point. Even though AC charging is the priority, DC charging is also considered by vehicle OEMs like Ather Energy that offer to their customers not only home charge points but are also developing a network of public charging points. Partnering with vehicle OEMs could therefore be a route to market for UK charge point manufacturers.

As well as providing reliable home charging for private consumers, public charging infrastructure also offers opportunities for foreign players. Affordable and reliable mass-market charging solutions for public infrastructure, such as on-street, car parks and shopping centres,

present another lucrative opportunity and can support mass uptake of EVs in India. Products developed for the UK market could also be used in India, but some considerations should be made. Space availability, especially for on-street charging, is an issue, therefore small and compact charge points are preferred.

As discussed in previous sections, India is seeing higher rates of EV uptake in the two- and three-wheeler segments. These vehicles have smaller batteries and would use different charging connectors compared to cars, meaning charge rates required might be different. Most vehicle OEMs are monitoring performance and collecting user data to improve their offerings and product design. The data collected serves as a valuable source of information on consumer charging requirements and will facilitate a better understanding of the type of public charging infrastructure that needs to be in place.

Finally, the battery swapping market which is likely to continue to co-exist with charging infrastructure offers opportunities ranging from consultancy services on the design of swapping stations, to supplying components and software solutions for battery charging optimisation.

Other opportunities that have been identified for UK companies in the space of charging infrastructure include:

- Visibility of charging infrastructure: Online platforms that offer information on type of charging infrastructure, location, availability, and real-time status are in high demand.
- To support mass uptake of EVs, ease of use of charging infrastructure will be vital including payment methods that will allow users to access public charge points without the need for multiple memberships.
- Use of data (geospatial, network availability, traffic, consumer demand etc.) to support local authorities and industry identify areas suitable for charging infrastructure.
- Smart charging products: This is a wider area that can include a range of products from smart charge points, smart metering equipment, electricity network monitoring, smart home devices to control home PV generation and charging, development of new business models
- Alternative charging technologies, such as inductive charging, for on street and public charging that will tackle issues like space availability and need for cable connection.

5.3 Energy system

Supplying green electricity for EV charging and taking advantage of the flexibility offered by EVs are longer term targets for India. Changes in the electricity market would need to happen first but there still areas where innovation is needed today, and UK companies can play a role.

Indian organisations such as The Energy and Resources Institute (TERI)[57] and the Centre for Study of Science, Technology and Policy (CSTEP)[58] have developed energy system models. Partnerships with these organisations to further expand current modelling capability and assess the impact the electrification of the transport sector will have in India will generate insights on the impact of smart

charging and modal shifts and electricity consumption today and in the future.

Demand also exists for technologies that increase understanding and visibility of the electricity grid state, both today and in the future. This could include a range of measurement technologies, state estimators and forecasting options. Furthermore, to support active network management in the future, automatically controlled interventions will be needed such as storage, compensation and filtering.

To deliver consumer propositions which successfully access flexibility, a range of technologies are needed and there is an opportunity for UK companies to participate in this market in the future. Demand will exist for technologies that decouple capacity requirements of the grid from charging times and places. Another identified opportunity is to provide the communication systems, business models and platforms that will harness the flexibility offered by EV charging and will deliver economic and efficient grid operation and grid reinforcement.

Finally, as cities in India are expanding but also moving to mass uptake of EVs, tools that provide a richer understanding of how transport, power, energy and town planning interlink and can be coordinated will be needed. UK expertise in that area could support decision making and promote collaborative and cross sector (linking the automotive and energy sectors) planning processes.

5.4 Opportunities Summary

Sector	Opportunity
Electric Vehicle	• UK innovations and IP in EV components leveraged for JVs in India. • UK advanced manufacturing techniques expertise to help localise EV supply chain in India. • Innovative battery technology expertise and IP • Data based fleet optimisation software and services. • Software solutions to provide accurate, real-time and context-sensitive information to the user about the vehicle available range and battery health during journeys • Software/platforms to facilitate journey planning
Charging Infrastructure	• Partnerships with Indian vehicle OEMs to provide charge point hardware and software. • Affordable and reliable public charging infrastructure, with appropriate considerations for Indian market. (two- and three- wheeler compatible) • Battery swapping technologies. • Online platforms for charging infrastructure visibility.
Energy System	• Partnerships with research organisations in India (e.g. TERI and CSTEP) to expand modelling capability and assess impact of electrification of transport on energy system. • Systems that expand understanding and visibility of current and future of Indian energy system. • Automatically controlled interventions; storage, compensation and filtering. • Technologies to decouple grid from charging demands. • Communications, business models and platforms to support flexibility services related to EV charging. • UK expertise to support decision making and promote collaborative and cross sector planning processes.

6. Understanding the Indian EV customer

Whilst attitudes to electric vehicles are generally positive in India, adoption remains low. The comparatively high cost of (particularly lithium-ion) EVs is a central prohibiting factor, but other unmet needs are also standing in the way of adoption. To boost their chances of success, EV innovators should carefully consider what users and customers want and need from EV products and services and tailor their offering accordingly.

In 2019, as part of the Innovating for Clean Air project, we carried out a mixed-methods, qualitative study on attitudes towards and experiences of electric vehicles among Bengalurean transport users and local businesses. The research was focused on electric two- and three-wheelers. In this section we integrate findings from this work with other research[59,60,61,62] on the attitudinal barriers and drivers for EV uptake. Of course, our findings were based on a small group in a single city - we recommend companies considering this market conduct further investigation as part of a market scoping exercise.

6.1 Price and cost

Price is a dominant choice driver in most countries, but this is especially true in India where a large domestic market and open competition has meant that consumers generally have a range of cost-effective options available to them. As such it is critical that due consideration is given to pricing and positioning, in particular the following aspects:

Up-front costs

In the context of EVs, while the total cost of ownership (TCO) is tending towards that of ICE vehicles, up-front costs are often still higher. A focus on reducing up-front cost - for example through subsidies, increased manufacturing efficiency, or innovative financing models - could be important in accessing the mass market. For professional drivers, non-ownership service models that entirely negate upfront, battery replacement and maintenance costs would be an interesting model. Similarly, recycling/upcycling/retrofitting solutions could help alleviate the cost involved in transitioning to EVs.

Clarity on TCO

Currently, prospective buyers are uncertain about the TCO of EVs - for example how often the battery needs replacing as well as the costs of charging and maintenance. Consumers could benefit from tools to calculate the cost of owning and using an EV when current travel habits are accounted for. Similarly, businesses would likely value tools to estimate short- and long-term savings involved in switching to EV. The UK's government-industry funded Go Ultra Low[xvi]offers information and tools to help private users and businesses work out, for example, journey cost, home charging costs or tax savings and could provide a model for this type of solution.

xvi https://www.goultralow.com/

6.2 Product

Positive characteristics to communicate

Indian driving conditions are in general well suited for electric vehicles. The comparatively low driving speed, start-stop nature, high share of idling time and shorter trip distances characteristic of Indian driving are all factors that make EVs a better choice than ICEs. With their ability to navigate congested roads with relative ease, electric two-wheelers are even more suited for Indian cities than electric four-wheelers are.

Areas of concern to address

Safety Prospective users want to know that the vehicles will perform safely and flawlessly under Indian driving conditions, such as uneven road surfaces, start-stop driving style, exposure to high temperatures and heavy rain. Some of the Indian vehicle certification requirements address these concerns - as discussed in Section 8.1.

Performance In particular, professional drivers and fleet operators considering a switch to electric need reassurance that the new vehicles will meet business requirements, especially when it comes to speed, range, acceleration, capacity and torque.

Further customising performance of EVs (for example with battery management systems, as noted in section 5.1) to optimise performance to driving needs and road conditions can help provide this reassurance - as well as effective communication, discussed below.

Test drives

Allowing prospective customers to test-drive an EV before the purchase can help remove any doubts about the driving experience. In fact, end-users in our research felt that first-hand experience of driving an EV would be the single most effective driver of adoption. In the UK, initiatives such as the EV experience centre[xvii] encourages adoption of four-wheel EVs by offering impartial advice and the chance to test-drive different vehicle models. Car dealerships and rentals could serve a similar role by allowing customers to test drive electric vehicles.

6.3 The experience of driving and maintaining EVs

Products and services tend to get adopted if they provide a better, ideally cheaper and more convenient way of achieving user goals. To achieve widespread EV adoption, they need to be similar to petrol vehicles in terms of user experience - and get over the 'hump' of breaking existing consumer habits and establishing new ones.

From a customer point of view, the tasks of recharging and paying attention to available range stand out as the most prominent differences between using an electric vehicle versus an ICE

xvii EV Experience Centre, Milton Keynes: https://evexperiencecentre.co.uk/

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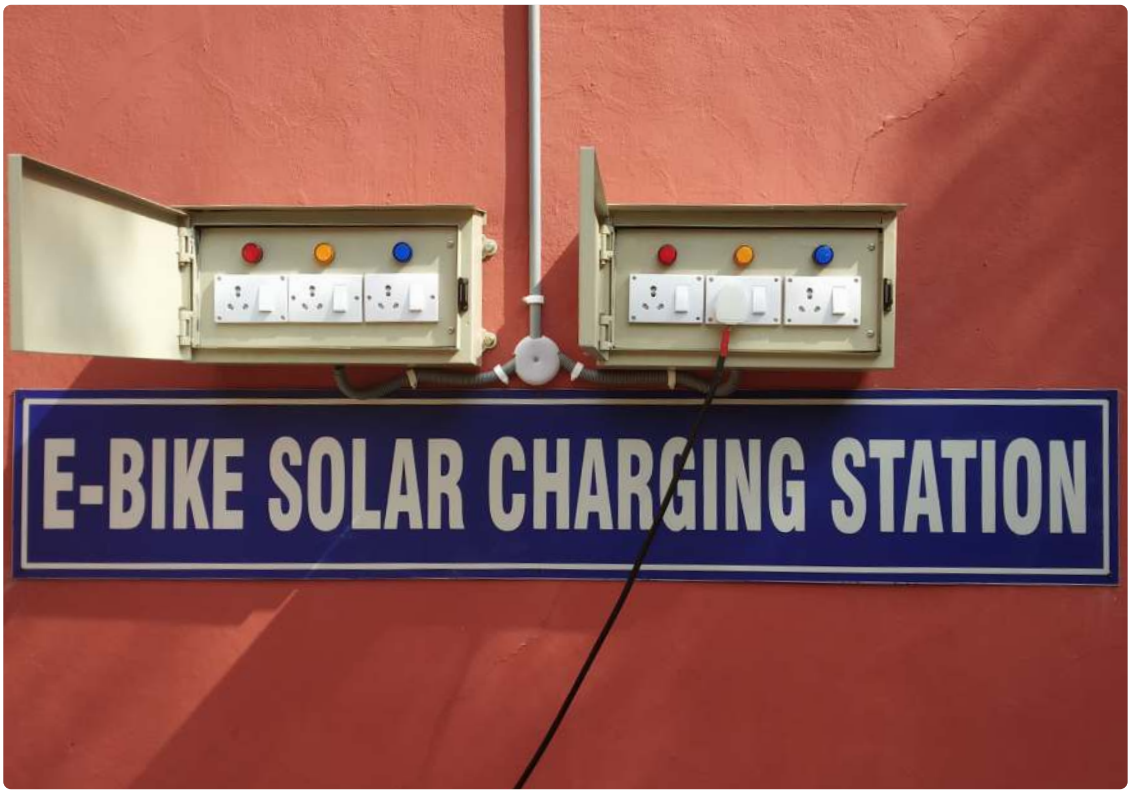

vehicle. To ensure the experience of owning and driving an EV is as comfortable and convenient as it is to use an ICE vehicle, EV innovators should try to address actual and perceived concerns and needs relating to charging and range.

Charging

Two-wheeler owners

For personal use customers in the two-wheeler market, concerns about charging are more perceived than experienced. In our research, we found that prospective personal-use customers were worried that charging would:

- Disrupt travel routines
- Be problematic due to power cuts
- Reduce flexibility due to the need to charge while travelling

In fact, current two-wheeler drivers:

- Rarely charge daily
- Usually only 'top up' while out of home and find the planning required similar to that for a petrol vehicle (some found it actually increased flexibility)

Research by Ather Mobility confirms the dominance of at-home charging for electric two-wheelers with the finding that 94% of their customers' charging is done at home[63].

Professional drivers and fleet operators

While EVs offer an attractive opportunity particularly to *new* fleet operators, able to invest in infrastructure at the same time as vehicles, inadequate provision of public charging is a genuine problem for professional drivers and fleet operators who are unable to afford replacing their fleets and building their own charging network. Specific issues include:

- Vehicles are driven further each day than an average battery can handle without recharging
- Drivers cannot afford to stop and charge for several hours during the workday
- Super-rapid charging is currently too expensive

While increased public charging provision around, for example, major transport hubs might help serve some of this demand, new solutions are needed to ensure professional drivers and businesses do not have to interrupt operations to recharge. In addition to more cost effective rapid-charging technologies, one of the more promising solutions to this would be battery swapping services, which we have discussed in more depth in section 4.4. (see also, e.g., Ola Mobility Institute 2019, or SIAM 2017[64])

Range Anxiety

As noted earlier, EVs are in general well suited to the characteristics of most Indian trips. For example, one study found that the average Bengalurean commuter travels 19 km per day or less, while most fully charged electric scooters will travel 60-80 km before having to be recharged[65]. However, range anxiety persists. Research cited by the Economic Times (2018) found that "about 70 per cent of the respondents believed that an electric car could provide a maximum mileage of 70 km per charge, while the basic models of electric cars available in the Indian market today deliver a mileage of over 100 km per charge."[66]

Better and more timely information can help address concerns about range and charging[xviii] [xix]. For example, real-time updates about charge point availability and battery status could reassure users that a flat battery will not leave them stranded by the side of the road. User-support for new customers can help them understand what a typical charging pattern/routine would look like based on their current travel patterns and living conditions. Similarly, businesses could benefit from tools to help work out how much power operations will require, and to what degree public charging infrastructure can accommodate this without disrupting operations.

Service and maintenance

There is a vast and knowledgeable workforce of mechanics in India who can fix and maintain

xviii In our research, we found that consumers desired in-journey information about: Where nearest charging stations are located; Battery status (% charge left); Distance that the vehicle can travel on current battery status; When the battery is running low; How to best plan trips, including where to stop and charge. At charging stations, users want information about: How to plug in, connect and charge in a safe way; Cost/charge; Time to reach a particular charge (%); Amount of charge provided (%); and Power capacity options for different models

xix Although focused mainly on electric 4W vehicles, PwC (2019) propose that two of the most critical bits of information to communicate to prospective customers are accurate, real-time and easily accessed information about public charging availability and how the capacity of different EV models meet the traveller's actual needs (for example in terms of range/charge vs average actual travel distance).

ICE vehicles. This provides some confidence to the mechanically inept, even as they travel far from their home locations. The same is not yet true for electric vehicles and as such there may be a need to bundle in these elements to an overall package for buyers in the form of long-term contracts - or as part of a 'vehicle as a service' model. Similarly, while there is vibrant second hand and scrap market available for ICE vehicles, end-of life support and recycling routes are not yet clear and established for EVs.

6.4 Marketing and communications

Because the EV sector is still nascent in India, albeit receiving a significant push from government, there are both challenges and opportunities for new companies in terms of marketing and communications. Opportunities in the sense that the territory is there to be occupied and space for new brands to emerge. Challenges in that the baseline level of knowledge about EVs in India is relatively low and various perceived challenges need to be addressed.

Attitudes and driving EV adoption

In our research, users considered EVs as positive for the environment both in terms of reducing emissions, but also in terms of air and noise pollution. Therefore owners and users of EVs were seen as eco-conscious front-runners, positively influencing others and subject of much admiration.

This point around status is important however - in India, in relation to vehicles, status is largely communicated by the cost and size of your private vehicle. If you can afford a motorbike you retire your pedal cycle and if you can afford a car you ditch your motorbike. For EV manufacturers (particularly of two wheelers), this suggests:

- There is a need for clear branding on products, communicating a premium eco-friendly positioning
- Merchandising (see GoZero Mobility case study, section 9) can support this; giving people the means to signal their eco-credentials
- Advertising can help build associations with an elite lifestyle; potentially with appropriate celebrity endorsements (as was done in Norway in the 1980s[xx])
- The mass market for private owners will be challenging to crack until the up-front cost of EVs reaches price parity with ICE alternatives

Addressing perceived barriers

As discussed in earlier sections, in addition to ***actual*** challenges with running EVs, there are various perceived barriers which need to be addressed in order to drive adoption.

xx https://reasonstobecheerful.world/norway-gm-electric-cars-morten-harket/

Range, Charging and Performance

As we have noted, prospective buyers have usability related concerns about EVs as well as apprehension about learning how to use new technology. In addition to providing support to new users through good after-sales service, these concerns can be addressed by wider ecosystem level 'myth busting' and education campaigns (ideally including government agencies).

Safety

Our research uncovered concerns about public charging infrastructure and equipment safety. Certification and standards, as discussed in section 8.1, supported by user-friendly design and instructions on charging sites can help here.

6.5 Building an ecosystem

The complex EV ecosystem that determines the user experience is not well understood by end-users and customers. Also, important links between the different nodes and agents in the system may be missing altogether. In a UK EV stakeholder consultation, a cross-Catapult consortium similarly observed that the critical relationships underpinning successful technology adoption are intricate and complex in the case of electric vehicles (FCC et al. 2018:9):

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Shutterstock.com

"Some technology developments bring completely new products and services to customers while others evolve existing services with enhancements and new features. Typically, the relationship is between the technology provider or his reseller and the customer, with the user experience being determined by them.

The relationships involved in creating the user experience for those transitioning to EVs, based on currently available technology is, however, much more complex. A user's experience is dependent not only on the technology provider, in this case the vehicle manufacturer and dealer network, but also on the delivery of policy and services from many other stakeholders."[67]

Fostering consumer trust in the EV ecosystem will help make the risks involved in trying these new technologies acceptable and allowing users to take a leap of faith into the unknown. To this end, each individual player in the ecosystem would do well to understand and build connections with others - be they component manufacturers, service providers, infrastructure companies or others - creating a good holistic user experience cannot be done alone.

For more insights and recommendations on user experiences, data ecosystem, digital technologies and standards within the EV sector as well as major issues impeding the transition to wide scale adoption of passenger electric vehicles globally, please read here and here.

7. Policy

7.1 Policy Background

Government policy has been critical to the evolution of EVs in India and elsewhere. For instance, the Chinese EV market - which now accounts for the largest share of global EV sales (53% in 2019) - has greatly benefited from its New Electric Vehicle Policy.

In India, the National Electric Mobility Mission Plan (NEMMP) in 2013 set the scene for its EV landscape. While the number of on-the-road EVs today is far short of the target of 6-7 million set by the Plan, it helped galvanize the market ecosystem including investors, manufactures and service providers. The government's FAME initiatives i.e., FAME-I (2015-19) and FAME-II (FY2019-22), have to some extent supported the foundational demand needed to establish industry know-how and the supply chain. Apart from subsidies, the policies have provided grants for pilot projects, R&D and charging infrastructure. With more than 20 OEMs active in the country, the two-wheeler segment has seen the most activity since the introduction of FAME-I.

	E-2Ws	**E-3Ws**	**E-4Ws**	**4Ws (Strong Hybrid)**	**Electric Buses**	**Charging Infrastructure**
Total number of EVs that can access incentives	1,000,000	500,000	35,000	20,000	7,090	2700 charging stations
Approx. Battery Size (kWh)	2	5	15	1.3	250	
Incentive per EV (£)	200	500	1500	130	50000	n.a.
Total incentives (£m)	200	250	52.5	2.6	355	100
Demand Incentives per kWH	INR 10,000 (£100); max. cap 20% of total cost of vehicle				INR 20,000 (£200); max. cap of 40% on vehicle costs	n.a.

Table 8 FAME-II Incentives - Rollout Plan (FY2020-2022) (Source: Department of Heavy Industries)

FAME-II aims to build on this foundation and offers more upfront incentives for EV purchases. Demand incentives are provided to buyers in the form of a reduced upfront purchase price, which are reimbursed to OEMs by the central government. These incentives cover all major categories - electric two-, three-, four-wheelers (electric, plug-in hybrid and strong hybrid[xxi]) and electric buses.

xxi Strong hybrid cars are powered by a combination of ICE and electric motors, however, in the case of strong hybrids the two power sources can operate entirely independently of each other. With more battery capacity, strong hybrids can drive further than mild ones on electric power only.

OEMs need to meet several eligibility criteria to benefit from government incentives. A key one is that for all EV segments except electric two-wheelers, incentives are only offered to vehicles used for public transport or for commercial purposes. For two-wheelers, incentives are available for private use as well as for public transport or commercial purposes.

In addition, state governments have announced their own incentives for manufacturing of EV components in their states. For charging infrastructure, FAME-II provides for the setting up of 2,700 charging stations across 62 cities. These charging stations are being deployed by various public sector undertakings (PSUs) in India including REIL and EESL.

Apart from these policies, the government's fiscal measures include a lower Goods and Service Tax (GST) for EVs, reduced to 5% from 12% in 2019, compared to 28-43% for ICE vehicles (The Economic Times, 2020)[68]. However, duty structure on components and batteries is bit more complex currently. For instance, a lithium-ion battery fitted in an EV attracts 12% GST, but a separately sold battery attracts 18% GST[69]. For fleets, the national government plans to make it mandatory for ride-sharing companies such as Ola and Uber to have 40% of their fleets as electric vehicles[70].

The variability in incentives between states is another factor worth considering. So far, around 14 Indian states have final or draft EV policies. The states with approved EV policies include Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, New Delhi, Tamil Nadu, Telangana and Uttar Pradesh. The states with draft policies include Bihar, Gujarat, Himachal Pradesh, Punjab and Uttarakhand. Nearly all the states' EV policies prioritize two and three-wheelers, public transportation and manufacturing. However, the policies differ in terms of EV targets, incentives for manufactures and consumers, and investments in charging infrastructure.

Of the states with approved policies, the states of Andhra Pradesh, Karnataka (mainly driven by demand in the city of Bengaluru), Maharashtra, Delhi, Kerala and Telangana stand out in terms of targets and investment. States such as Delhi, Uttarakhand and Tamil Nadu have set segment-specific targets for EV conversion. Delhi mandates conversion of two-wheeler fleet of delivery companies to 50% by FY23 and 100% by FY25. Other states could follow suit soon.

A range of details on FAME-II and the PMP including a list of FAME-II certified EV dealers and OEMs can be found **here** and **here**.

7.2 Policy Limitations and Eligibility Criteria

FAME-II incentives entail a range of eligibility criteria for vehicles including price, range and speed, and use of local supply chains for manufacturing. Table 9 outlines some of these criteria; further details can be found here. Significantly, to access the incentives all EVs must be manufactured locally in India and have at least 50% of components sourced locally. OEMs across categories currently struggle to meet the 50% localization criteria[71] for manufacturing EVs. Most domestic manufacturers currently do not make lithium-ion batteries, electric motors and other specific parts used in EVs. Complex certification procedures also discourage the industry. These complicated conditions have meant only under 2% of the target number of EVs were subsidised under FAME-II by end of September 2020 (Economic Times, 2021)[72].

In addition, four-wheelers, for instance, must be priced under INR1.5million (c.£15,000) to access the incentives. Criteria such as a minimum range of 140km for smaller passenger cars (M1 category) and minimum 'highest' speed of 70km/hour reduce the number of models eligible for incentives significantly. Indeed, as of March 2019, none of the manufacturers offered passenger vehicles that met these criteria (Livemint, 2019)[73].

EV Segment	CMVR Category[xxii]	Max. Ex-factory Price	Min. range	Max. energy consumption (kwh/100 km)	Min. Highest Speed (km/hour)	Min. Acceleration (m/s2)	Maximum Price (ex-factory, £)	Max. Battery Capacity (kWh)
E-2W	L1, L2	1500	80	7	40	0.65	1500	3
E-3W	e-rick[xxiii]/ e-cart	5000	80	8	n.a.	n.a.	5000	5
E-3W	L5	5000	80	10	40	0.65	5000	10
E-4W	M1	15000	140	20 (for length >/ 4m); 15 for (length < 4m)	70	1.04	15000	30
E-4W	N1/M2[xxiv]	15000	100	30	50	1.04	15000	20

Table 9 Vehicle Eligibility Criteria under FAME-II (Source: Department of Heavy Industry) (Note: Apart from the above mentioned criteria, all EVs (except e-rickshaw/e-cart), are required to be equipped with an 'Electric Regenerative Braking System' and 'Advanced Battery' (See Glossary) .

xxii As defined in the Central Motor Vehicles Rules (CMVR), 1989. See Vehicle Types in India.

xxiii Including e-autos and registered e-rickshaws

xxiv Include light commercial vehicles (LCV), Stage Carriages, Maxi cabs etc.

7.3 Industrial Policy Comparison by States

Along with central government policies, several state governments have introduced their EV policies focused on incentives for OEMs (supply-side incentives) to attract investment and generate employment in their states. States like Andhra Pradesh, Uttar Pradesh, Tamil Nadu and Gujrat offer incentives such as capital interest subsidy, stamp duty reimbursements, tax exemptions, SGST (State Goods and Services Tax) reimbursement and provision of interest free loans to incentivize EV manufacturers. Table 10 provides a comparison of the key aspects of these state policies. Most of the state incentives are also available for foreign companies establishing manufacturing/ industrial facilities in India.

		Gujarat	Maharashtra	Karnataka	Uttar Pradesh	Tamil Nadu	Andhra Pradesh
Capital Incentives	Stamp Duty Exemption	✓	✓	✓	✓	✓	✓
	Interest Subsidy	×	✓	✓	✓	×	×
	Infra Interest Subsidy	×	×	×	✓	×	×
	Capital Subsidy	✓	×	✓	×	✓	✓
Operational Incentives	EPF Reimbursement	×	×	×	✓	×	×
	Indirect Tax Subsidy	✓	✓	✓	✓	✓	✓
	Electricity Duty	✓	✓	✓	✓	✓	✓
	Interest Subsidy in Industrial research	×	✓	✓	✓	×	×
Bespoke Incentives package based on investment size		✓	✓	✓	✓	✓	✓
Differential incentives package based on location		✓	✓	✓	✓	✓	

Table 10 Industrial Policy Comparison of Key states (Source: NITI Aayog, 2020)

Parameter	Maharashtra	Haryana	Madhya Pradesh	Gujarat	Tamil Nadu
Policy (apart from industrial)	Electrical Vehicle and Related Infrastructure Policy 2018	Part of industrial investment and business promotion	Electric Vehicle (EV) Policy 2019;	Manufacturing sector schemes; EV Policy 2019	Automobile and Components Policy; EV Policy 2019
Major Incentive/ Subsidy	100% Fixed Capital Investment subsidy. 20% reserved area for MSMEs[xxv] in new industrial estates.	Interest Subsidy Scheme @6% for auto component manufacturers (MSMEs) for 5 years. Reimbursement of 75% SGST paid up to 7 years.	50% of fixed capital investments and 25% of the value of the charging station for first 300 units. 10% of FCI for first two units of EV manufacturing	Interest Subsidy is provided @ 7% for MSMEs and 2% for Large Industries. Reimbursement of up to 90% of SGST for a period of 10 years depending on fixed capital investment.	100% reimbursement of SGST paid on the sale of EVs manufacture, sold and registered for use in the State.
Major clusters	Mumbai, Pune (Chakan), Nashik, Aurangabad, Nagpur	Gurugram, Faridabad, Manesar, Rewari, Panchkula	Indore; Pithampur; Mandideep; Govindpura	Ahmedabad, Sanand, Mehsana Hansalpur, Vithalpur; Dholera; Rajkot Vadodara	Chennai – Sriperumbudur, Oragadam, Maraimalai

Table 11 Illustrative list of manufacturing incentives offered by select states (Source: EY India, 2020)

xxv Micro, Small and Medium Enterprises, as defined here

8. Legal and Compliance

Policy makers in India are looking at EVs as a potential solution to India's pollution problem and to help meet carbon emission reduction goals. EVs are being encouraged with favourable policies such as capital expenditure assistance, tax and permit exemptions and protection for domestic manufacturers. In this section we outline the aspects of the Indian legal and policy system which are relevant to foreign companies seeking to enter the market.

8.1 Indian Regulatory and Tax Regime

Foreign Investment

India allows 100% foreign investments in the EV industry and related infrastructure activities. Foreign companies can establish a presence in India through subsidiaries, Joint Venture (JV) and Limited Liability Partnership (LLP)[xxvi]. Details of these options can be read here. Cross border loans (e.g. from the UK to the Indian entity) are permitted under exchange control rules for capex / working capital purposes subject to minimum maturity and interest rate caps. Payment of considerations for technical services / royalty or repatriation of profits via dividends / buyback is also permitted under exchange control rules. Corporate law in India requires at least one director of the Indian company to be resident in India while others can be non-resident.

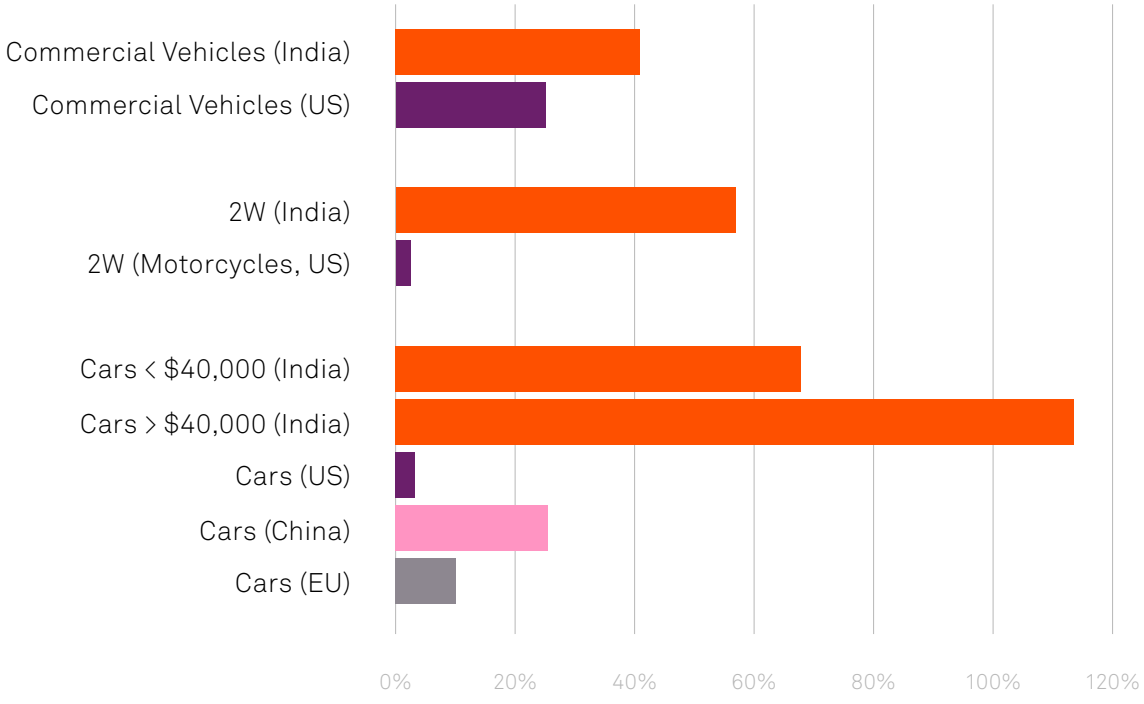

Figure 15 EV Tariffs in India and Other Countries by Vehicle Segment (Source: Economic Times, 2020)

Customs Duty

xxvi An LLP is a body corporate and legal entity separate from its partners. Every LLP shall have at least two designated partners being individuals, at least one of them being resident in India and all the partners shall be the agent of the Limited Liability Partnership but not of other partners.

India has amongst the highest import tariffs on vehicles globally. This means globally popular EV models are unavailable in India.

India allows a rebate of 0-10% on customs duty on imports from preferred trade nations; UK is currently not in the list of preferred trade nations, and although trade talks are ongoing[74] there is as yet no substantive trade deal or timeline to agree one.

Customs duties may also be avoided if importing into Special Economic Zones (SEZ) - of which there are more than 250 in India[75]. These zones are typically used as low-cost manufacturing zones for goods intended for export from India but may also be used to access the domestic market (though at that point - upon entry to the Domestic Tariff Area (DTA)) - duties would be payable.

The Project Import Scheme (PIS)[76] can be used by companies in the EV market to obtain reduced customs duty on capital goods and spares up to 5%. There are also export trade incentives including the Merchandise Exports from India Scheme (MEIS) and Services Exports from India Scheme (SEIS)[77] for manufacturing/services exports from India, under which the government provides up to 5% incentives to exporters.

Taxation of Foreign Companies in India

As can be seen from the tables below, the tax rules in India are complex. Engaging a local firm to advise is highly recommended.

Income*	Corporate Income-Tax (CIT) rate (%)					
	Turnover does not exceed INR 4 billion in FY 2017/18		For other domestic companies		Foreign companies	
	Basic	Effective**	Basic	Effective**	Basic	Effective **
Less than INR 10 million	25	26	30	31.2	40	41.6
More than INR 10 million but less than INR 100 million	25	27.82	30	33.38	40	42.43
More than INR 100 million	25	29.12	30	34.94	40	43.68

* Surcharge of 7% or 12% (calculated on basic tax payable) is payable only where total taxable income exceeds INR 10 million. The rate of surcharge is 7% for total income above INR 10 million and less than INR 100 million. The surcharge is 12% for total income above INR 100 million. **Effective tax rates include the effect of surcharge and 'health and education cess'[xxvii]

Table 12 Corporate income-tax (CIT) rate applicable to an Indian company and a foreign company for the tax year 2020/21 (Source: PwC, December 2020)

xxvii A fixed percentage of levy (4% as of FY 20/21) on the total tax and surcharge liability of a taxpayer. The main objective of this cess is to meet the expenditure towards fulfilling the Government's commitment of providing quality basic and higher education to the poor children and ensure basic health amenities to the needy. Unlike surcharge, there are no taxable income thresholds for health and education cess – needs to be paid by all domestic and foreign companies.

Notably, newly set-up domestic manufacturing companies and power generation companies that meet certain eligibility criteria are subject to a reduced rate of CIT of 15% (plus 10% surcharge and 4% health and education cess) announced in 2019 and 2020[78].

Minimum alternative tax (MAT)

Companies are liable to pay MAT on their adjusted book profits (unrealised profits, other than income from life insurance business) where the basic tax liability under the normal provisions (excluding surcharge and health and education cess) of the Income-tax Act is not more than 15% of such book profits.

MAT provisions are only applicable to foreign companies with a permanent establishment (PE)[xxviii] in India.[xxix] Capital gains, such as from transfer of securities, interest and royalties, of a foreign company with a permanent establishment in India are excluded from MAT if tax payable on such income is less than 15% (exclusive of surcharge and health and education cess).

Notably, companies operating in the SEZ also liable to pay MAT.

The existing tax rates under MAT are provided in the below table:

Income*	MAT rate (%)			
	Indian company		Foreign company (other than exempted)	
	Basic**	Effective***	Basic**	Effective***
Less than INR 10 million	15	15.6	15	15.6
More than INR 10 million but less than INR 100 million	15	16.692	15	15.91
More than INR 100 million	15	17.472	15	16.38

* Surcharge of 10% is payable only where total taxable income exceeds INR 10 million. ** Basic rate of MAT is 9% of book profits in case of a corporate and non-corporate taxpayer located in an International Financial Services Centre and deriving income solely in convertible foreign exchange. *** Effective tax rates include surcharge and health and education cess.

Table 13 MAT rates applicable to Indian and foreign companies for the tax year 2020/21 (Source: PwC, December 2020)

Apart from these, long-term[xxx] capital gains arising to a foreign company such as from transfer of unlisted securities, shares and debentures, are taxable at 10% (plus surcharge and health and education cess)[79].

More details on corporate income tax in India can be found **here.**

xxviii The term PE, under Article 5 on Double Tax Avoidance Agreements (DTAA) that India has signed with various countries, is defined as "a Fixed place of business through which the business of an enterprise is wholly or partly carried on. For more detail, please read here.

xxix Exempt companies include companies that generate revenue solely from shipping business (carriage of passengers, livestock, mail, or goods from Indian ports), exploration of mineral oils, business of aircraft, civil construction in turnkey projects.

xxx Depending on how long they are held, assets may be considered 'short term' or 'long term See here.

Phased Manufacturing Program (PMP)

The Indian government's PMP (linked with FAME-II) aims to establish a local EV supply chain in the country in a phased manner. Companies looking to access demand incentives under the FAME-II scheme are required to gradually increase local sourcing of components for their EVs as stipulated in the PMP (Figure 16). In October 2020, the government extended the deadline for mandated local procurement for some components including traction motors, motor controllers, vehicle control units, on-board chargers, convertors and instrument panels to April 2021 (The Economic Times, 2020)[80].

No.	Category / Item Description	e-2W	e-3W	e-4W	e-4W	e-Buses
		L1 & L2	E-Rickshaw & E-Cart	L5	M1	M2/M3
1	HVAC	N/A	N/A	B	B	E
2	Electric compressor	N/A	N/A	E	E	E
3	Power and control Wiring harness along with connectors	A	A	B	B	E
4	MCB / circuit breakers / electric safety device	A	A	E	E	E
5	AC Charging inlet Type 2	N/A	N/A	E	E	E
6	DC charging inlet CCS2 / CHAdeMO	N/A	N/A	E	E	E
7	DC charging inlet BEVC DC 001	N/A	N/A	E	E	N/A
8	Traction battery pack	A*	A*	A*	A*	E
9	Wheel rim integrated with Hub motor	E	B	E	E	E
10	DC - DC converter	E	B	E	E	E
11	Electronic Throttle	E	E	E	E	E
12	Vehicle control unit	E	E	E	E	E
13	On Board Charger	E	E	E	E	E
14	Traction Motor	E	E	E	E	E
15	Traction Motor controller / inverter	E	E	E	E	E
16	Instrument Panel	E	E	E	E	E
17	Lighting: Headlamp, Tail map, indicators, Interior Lamp, Flasher etc.	E	A	E	A	A
18	Body panel	E	A	E	A	A

Note: Traction battery pack to be assembled domestically, for which battery cells and associated thermal and battery management system may be imported.

- All other Parts, Components, Assemblies or sub-assemblies, other than mentioned above should be domestically manufactured and assembled. CMVR notified safety components sohuld be tested by the testing agencies notified under rule 126 of CMVR, 1989.

Definitions: N/A — Not Applicable

Code	Effective date of indigenisation of xEV parts
A	w.e.f 1st April 2019
A*	w.e.f 1st July 2019
B	w.e.f 1st October 2019
C	w.e.f 1st April 2020
D	w.e.f 1st October 2020
E	w.e.f 1st April 2021

Imported source includes direct as well as indirect import.
Indigenous source implies domestically manufactured / assembled and tested.

Figure 16 PMP for EV Components to be Eligible Under Fame-II; Source: Department of Heavy Industries, Government of India, May 2019

Under PMP, customs duty on imported CBUs[xxxi], commercial SKD[xxxii] kits of partially assembled parts and CKD[xxxiii] parts of a product have also been increased. For personal vehicles (PVs), the basic customs duty (BCD) on SKD kits has been doubled to 30%. The increases have made several existing models in the country imported as SKDs or CBUs more expensive[81], with the increase in price passed on to end users.

Description	Vehicle Type	Current BCD	Proposed BCD	Deadline for Localisation
CBU	Bus & Trucks	25%	50%	
SKD	PV & 3W	15%	30%	April 2020 onwards
	2W		25%	
	Bus		25%	
	Trucks		25%	
CKD	Bus	10%	15%	
	Personal Vehicles (4W)			
	2W			
	3W & Trucks			
Lithium-ion cells for use in manufacture of Lithium-ion accumulator for EVs		5%	10%	April 2021 onwards
Battery packs for use in the manufacture of EVs		5%	15%	April 2021 onwards
Parts used in the manufacture of EVs like AMC charger, AC/DC motor, AC/DC motor controller. Power Control unit (Inverter, AC/DC converter, Condenser), Energy monitor, Contactor, Brake system for recovering, Electric compressor		0%	15%	April 2021 onwards

Table 14 Customs duty changes for various components (Source: Avendus Capital, 2020)

Under PMP[82], the traction battery pack[xxxiv] is to be assembled domestically, for which battery cells and associated thermal BMS can be imported.

xxxi Completely Built Units refer to imported cars and bikes which are direct bought in ready shape for its sale

xxxii Semi Knocked Down Units refer to "working" finished vehicles, subsequently knocked down into a very limited number of parts

xxxiii Completely Knocked Down vehicles are characterised by a value higher than or equal to 40% of the equivalent CBU

xxxiv A traction battery back, mainly used for heavy industrial purposes including EVs, consists of several cells of 2 volts. When these cells are connected in series, they provide higher voltages. Traction batteries differ from starter batteries by providing a certain amount of energy for longer periods. As a result, traction batteries usually have a much higher capacity than starter batteries.

EV Regulations and Standards

EV regulations and standards in India falls under the Central Motor Vehicles Rules (CMVR) committee, set up by the Ministry of Road Transport & Highways, Government of India. The CMVR approves Automotive Industry Standards (AIS) prepared by the Automotive Industry Standard Committee (AISC)[83] in India. A list of EV-related AIS standards vis-à-vis reference multinational ECE (Economic Commission for Europe) standards is shown in Table 15.

For more details on each of the standard, please see here.

Indian Standard[84]	Reference International Standard
1. AIS 038 Revision 1: Constructional and Functional Safety Requirements[85] • Traction Battery Mounting, Ventilation Details, Circuit Breakers (fuses) power train protection devices, Creepage Distance • Protection against Electric Shock • Connection of vehicle to mains network for charging • Audible or Visual Indicators for active driving mode • Protection against water effects: Washing, Flooding, Heavy Rainstorm test **Upcoming Revision 2** is formulated for Vehicle and Battery Safety in-line with Global Technical Regulation (GTR) 20[86] for M & N Category vehicles (See appendices)	ECE R 100
AIS 039 Revision 1: Electrical Energy Consumption[87] • Test using driving Cycle on Chassis Dynamometer • Measurement of Energy Required per km: Wh/km	ECE R 101
AIS 040 Revision 1: Measurement of Range[88] • Test using driving Cycle on Chassis Dynamometer • Measurement of Distance covered by vehicle in one full charge	ECE R 101
AIS 041 Revision 1: Measurement of Net Power and The Maximum 30 Minute Power[89] • Measurement of Speed vs. Power • Measurement of 30 Mins Power	ECE R 85
AIS 049 Revision 1: CMVR Type Approval for EV	-

AIS 048 & Amendment 1 and 2: Performance and Abuse Testing for Traction Batteries[90]
 	
• Electrical Abuse Test
  • Short Circuit Test
  • Over-charge Test
• Mechanical Abuse Test
  • Vibration test
  • Mechanical Shock Test
  • Roll-over Test
  • Penetration Test
	USABC[xxxv], ISO/IEC[xxxvi] Standards

AIS 049 Revision 1: CMVR Type Approval for EV[91] • Brake performance and consideration of regenerative braking • Grade-ability Test (AIS- 003) at 60% state of charge • Speedometer Calibration Test • Pass by Noise • Electromagnetic compatibility (EMC) Test (AIS-004 Part 3)	
AIS 102 (Part 1[92] and 2[93]) with Amendment 1 and 2: CMVR Type Approval for Hybrid Electric Vehicles • Requirements specific to hybrid electric vehicles of M and N category, whose GVW does not exceed 3500 kg and L category vehicles, as per CMVR categorisation (See appendices). • Requirements specific to hybrid electric vehicles of M and N Category with GVW greater than 3500 kg, as per CMVR categorisation (See appendices).	ECE R 83, ECE R 100, ECE R 101
Draft AIS 156: Specific Requirements for L Category Electric Power Train Vehicles • Formulated for Vehicle and Battery Safety In-line with R 136 (L category vehicles)	ECE R 136
AIS 131[94]: Type Approval Procedure for Electric and Hybrid EVs introduced in market for pilot / Demonstration Projects • Type Approval Procedure for Electric and Hybrid EVs introduced in market for pilot / Demonstration Projects intended for Government Scheme	-
Standards for Chargers	
IS 17017 Series[xxxvii] [95]: Electric Vehicle Conductive Charging System Part 1 General Requirements	IEC 61851-1
Draft AIS 004 Part 3 Revision 1: Automotive Vehicles Requirements for Electromagnetic Compatibility[96]	ECE R 10.5

Table 15 List of EV Standards in India (Source: The Automotive Research Association of India (ARAI), 2020)

xxxv United States Advanced Battery Consortium

xxxvi International Standards Organisation/International Electrotechnical Commission

xxxvii Indian Standards, published by Bureau of Indian Standards (BIS)

Types of EV chargers in India

The revised guidelines from the Ministry of Power in 2019 removed the mandatory condition to install all types of chargers (i.e. Bharat AC 001/DC001, CCS, CHAdeMO and GB/T) at a public charging station and clarified that public charging stations shall have any one or any combination of chargers from the table mentioned below.

Charger Type	Charger Connectors	No. of Connecter Guns[xxxviii] (CG)	Rated Output Voltage (V)	Charging Vehicle Type (wheeler)
Fast	Combined Charging system (CCS) (min. 50 kW)	1 CG	250-750 or higher	4W
	CHArge de MOve (CHAdeMO) (min. 50 kW)	1 CG	250-500 or higher	4W
	Type-2 AC (min. 22 kW)	1 CG	380-415	4W, 3W, 2W
Slow/Moderate	Bharat DC-001 (15kW)	1 CG	48	4W, 3W, 2W
	Bharat DC-001 (15kW)	1 CG	72 or higher	4W
	Bharat AC-001 (10kW)	3 CG of 3.3 kW each	230	4W, 3W, 2W

Table 16 EV Chargers available at public charging stations in India (Source: IESA – India Energy Storage Alliance, 2020)

For low voltage EV Standards, IS 17017 recognises DHI (Department of Heavy Industry) approved Bharat Charger Specifications. As far as high voltage charging protocols are concerned, the IS 17017-1 published by the BIS (Bureau of Indian Standards) in August 2018, recommended globally popular CCS-2 and CHAdeMO protocols for this purpose. The BIS standard primarily refers to three IEC Standards: IEC 61851 (for safety provisions), 62196 (for plugs & sockets), ISO 15118 (for series of communication between EV & EVSE (Electric vehicle service equipment)) for the development of BIS standard series IS 17017[97].

Note that the draft AIS 004 Part 3 Revision 1: ***Automotive Vehicles Requirements for Electromagnetic Compatibility*** standard has some elements unique to India, concerning 2- and 3-wheeler chargers specifically.

More details on EV charging and EV standards in India can be found **here.**

xxxviii Charging gun refers to gun shaped charging point outlet

8.2 IP Protection

India has been a World Trade Organisation (WTO) member since 1995. WTO member nations must include some IP protection in their national laws. This means that if you are doing business with India, you will find some similarity between local IP law and enforcement procedures, and those in force in the UK.

India is also a signatory to the following international IP agreements[98]:

The Paris Convention: Under this, any person from a signatory state can apply for a patent or trademark in any other signatory state and will be given the same enforcement rights and status as a national of that country would be.

The Berne Convention: Under this agreement, each member state recognises the copyright of authors from other member states in the same way as the copyright of its own nationals

The Madrid Protocol: Under this, a person can file a single trademark application at their national office that will provide protection in multiple countries

The Patent Cooperation Treaty: This is a central system for obtaining a 'bundle' of national patent applications in different jurisdictions through a single application.

India is not a signatory to the Hague Agreement, which allows the protection of designs in multiple countries through a single filing.

Patents

India's Patents Act of 1970, 2003 Patent Rules and the 2016 Patent Amendment Rules set out the law concerning patents. As in the UK, there is no provision for utility model[xxxix] patents. Patents are valid for 20 years from the date of filing an application, subject to an annual renewal fee. India's patent law operates under the 'first to file' principle - that is, if two people apply for a patent on an identical invention, the first one to file the application will be awarded the patent.

Designs

The laws governing designs[xl] are the Designs Act 2000 and the Designs Rules 2001. Designs are valid for a maximum of ten years, renewable for a further five years.

xxxix A utility model is a patent-like intellectual property right to protect inventions. This type of right is available in many countries but not in the United States or United Kingdom. Although a utility model is similar to a patent, it is generally cheaper to obtain and maintain, has a shorter term (generally 6 to 15 years), shorter grant lag, and less stringent patentability requirements.

xl Patents prevent others from making or selling an invention, trademarks protect the words, phrases, symbols, logos, or other devices used to identify the source of goods or services from usage by other competitors and copyright protects published and unpublished original works. In contrast, a design right offers an exclusive right to its owner on the appearance of the product.

Trademarks

India's trademark laws consist of the 1999 Trademarks Act and the Trademarks Rules of 2002 and 2017.

Potential problems faced in India

India's IP legislation covers every significant aspect of the protection of IP. The regulations relating to all forms of IP have been amended or reissued in recent years, mainly in response to India's accession to the World Trade Organisation in 1995. Although Indian IP law is thorough and generally comparable with European IP laws, there are still significant concerns over IP enforcement - for example, bureaucratic delays. There is a backlog of cases at both the civil and criminal courts and cases can run for five years or more. There is also a lack of transparency, particularly at a local level. A significant feature of the IP environment in India is the large number of small players infringing IP rights. This means that seizures tend to be small, which requires a sustained and financially draining effort in order to make an impact. An advantage for UK businesses operating in India is that the legal system is based on common law, as in the UK, so the fundamental processes are familiar. Also evolving legal guidelines and recent court cases[99] provides positive outlook that the IP owners' rights are duly acknowledged and are being effectively enforced by courts.

As of 2020, India ranks 40th on the International IP (IIP) Index, which analyses the IP climate in 53 global economies[100].

9. Case Studies

Image credit:
© GoZero Mobility

9.1 GoZero Mobility

- **Founding Year: 2018**
- **UK Headquarters:** Birmingham, UK
- **Indian Locations:** New Delhi, Kolkata
- **Employees:** 14
- **Seed Funding:** c. £180,000 (Investor: KSL Cleantech)

GoZero Mobility (GoZero) is a British company that makes high performance e-bikes and active wear. GoZero began its journey in 2018 with a design team in Birmingham, UK. It developed various proto-models before launching a final product in India in 2019. The company is currently present in India through over 105 physical retail points and online sales through leading e-tailers. Its manufacturing setup is based in the city of Kolkata (West Bengal) with a capacity of 12,000 units per annum. The company is focused on direct consumers and aims to help them switch to a more active form of mobility, e-bikes.

Why India?

Attracted by India's history of being one of the largest cycle makers in the world, GoZero wanted to utilise the local capabilities and experience to build its e-bikes for the global and domestic markets. While the products are designed in the UK, the company is able to capitalise on the efficient, low-cost and skilled labour in India.

"The Indian EV market is at a very nascent stage and is poised to grow big in the coming years. There's certainly a first mover advantage for any international player to enter at this stage. Additionally, the component industry for electric mobility is growing and it gives a great advantage for companies to consider India as their manufacturing hub for global operations."

Ankit Kumar, CEO GoZero Mobility, Feb 2021

Market Entry - Designed in the UK, Manufactured and Sold in India

- GoZero partnered with Kolkata-based, Indian firm KSL Cleantech Limited for the development and manufacture of the e-bikes.
    - As part of the partnership, KSL Cleantech invested USD 250,000 (c. £180,000) in GoZero Mobility in the form of seed funding.
- 'Brand Britain' is an important selling point for GoZero which emphasises British design and heritage alongside Indian manufacture.
- The e-bikes are 60% locally manufactured in India. The other 40% consists of components imported from countries such as Taiwan, Spain and the UK. This helps the company take advantage of the lower manufacturing costs in India while avoiding excessive customs duties.

Performance

GoZero launched its initial e-bike models, GoZero One and GoZero Mile, in India in 2019, followed by the launch of the Skellig series six months later. It has since also launched a range of active performance wear and related products.

Generating £400,000 (INR 40 million) in FY2020 (through to January 2020) with sales of over 900 units, GoZero plans to double its revenue in FY2021 by selling a total of 3000 units in FY2021[101]. Merchandise offerings too have performed well for the company emphasising Indian consumers' propensity towards active wear that communicates the 'why' of using e-bikes i.e. being environmentally conscious or an 'active' traveller.

In terms of cities, at present, the majority of sales come from Karnataka, Delhi-NCR, Maharashtra, Odhisa and Andhra Pradesh. Cities such as Kolkata, Goa, Chandigarh, Pune are also showing fast growth.

Distribution Network

- The company's Skellig and Skellig Pro models are sold through online and physical channels, while Skellig Lite is sold online only, through the company's website and other e-commerce platforms.

- As of March 2020, 65% sales were generated online through Amazon India, while 35% come from offline retail networks, with the largest online sales coming from South India.[102]

Major Challenges

- **Funding:** Securing initial investment was a challenge. The nascent state of the e-bike market meant it took time and effort to convince KSL Cleantech to partner and invest.

- **Driving consumer behaviour change:** Driving adoption of e-bikes has been challenging, especially in northern regions such as Delhi-NCR where many Indian consumers associate cycling with a lower social status (as discussed in section 6.4.1).

- **Finding the 'right' vendors:** Initially, the company struggled to find vendors who could meet the company's terms. A nascent e-bike market meant the volumes were not enough for vendors to work with GoZero's target price bracket. To tackle this, GoZero developed a '3-vendor policy' under which it identified 3 vendors for a component, validated them and finally signed up a 3-year contract for procurement with defined quality benchmarks and projections. This approach worked for the company and also reduced its dependency on a single vendor for a component.

- **Post-Covid Breakdown in Logistics Network:** The end of pandemic-induced lockdown in India saw a sudden rise in demand for e-bikes; GoZero witnessed 300% growth at one point. The company's existing logistics partners were unable to handle this leading to significant delays in deliveries. Recognising this as a longer lasting problem, GoZero collaborated with other regional logistics players including start-ups that had available capacity and managed to reduce the delivery timeline from 25 to 7 days.

Government Support

- E-bikes are currently not included in government's subsidy/incentive offerings under the FAME policy. Although the company is in discussions at state government level to include e-bikes in their incentive policy, nothing conclusive has come out yet.

Future Plans

- GoZero is currently in the expansion phase and is building a new manufacturing facility in Delhi-NCR with capacity to produce an additional 12,000 units per annum.

- GoZero plans to introduce three new products in FY2021 including:

    - Its first B2B product GoZero 'Delivr' that will target **last mile delivery segment** that needs higher speed and range.

    - GoZero 'Lite' will be a mass segment product to be launched in August, priced at under

INR 20,000 (£200). The low-price tag is expected to drive significantly higher unit sales. Currently, major competitor Hero Electric's highest selling bike is priced at the lower end of the market between £170-180.

  - A third model targeting **female customers specifically.**

- In the last 6 months, GoZero has added over 70 retail points. Further, it plans to add more than 2000 retail points and 20 company-owned experience zones across the country. Its recent collaboration with Reliance Digital (the largest electronics store in India) will build its presence in 500+ cities in India.

- To boost active mobility culture, the company is also building various infrastructure such as e-bike charging and parking zones and cycle corridors. Notably, lack of public charging infrastructure - a major challenge that usually impedes the adoption of EVs - is less of a challenge for e-bikes as they come with detachable batteries that can be carried and charged at homes and offices, eliminating reliance on public charging infrastructure.

> India is a very vibrant country; every 200 Kms you can witness the diversity in culture, taste, preference levels, thought process etc. It took us sometime to understand the consumer preferences and accordingly place the product from market to market. Due to this reason, we initially only focused on select territory to expand and with time expanded to other regions. I do not think we regret, or it went bad for us but definitely wish to have known for a much faster expansion to other territories.

Ankit Kumar, CEO GoZero Mobility CEO, Feb 2021

Image credit:
© Latent Heat Solutions LLC

9.2 Latent Heat Solutions (LHS)

- **Founding Year:** 1990
- **Global Headquarters:** Golden, Colorado (US)
- **Indian Locations:** Currently being planned
- **Employees:** Around 20
- **Revenue (2019):** $3.88 million (£2.78 million)
- **Parent Company:** CAVU Group (Acquired in Oct 2020)

Latent Heat Solutions LLC is a Colorado (US) based company that offers thermal management solutions for battery packs for EVs including two- and there-wheelers and delivery trucks. Several of its products are designed for the high-ambient environments common in India[xli], allowing Indian EV OEMs to achieve significant reduction in peak temperatures. The company's solutions claim to improve battery safety and battery-life by 40% by reducing cell-degradation.

Market Entry and Opportunities

Prior to entering India, LHS was already active in other Asian markets where battery pack OEMs faced similar hot weather-related technical issues. Coupled with other supporting factors such

xli Refers to the temperature of the air surrounding a component. If the ambient temperature is high or low, some battery charge may be consumed to control the temperature.

as a growing EV sector (especially two- and three-wheelers) and widely spoken English, the company decided to explore the Indian market.

To better navigate the market, LHS partnered with Quanzen, a local market-entry specialist with a strong network in the sector.

FAME-II eligibility requirements (see section 7.2) meant several Indian EV OEMs had to upgrade their market offerings to access policy incentives. This resulted in an unanticipated opportunity for LHS which supported OEMs in the thermal management of the larger battery packs which were required to qualify for subsidies.

Efforts to improve durability and performance of battery packs imported from China have helped create a market for LHS's solutions that can be added to the imported product from China in India as a 'low-cost value-add'.

Challenges

- Working with larger, bureaucratic Indian companies can be time consuming.
- Shipping costs and high customs duties negatively impact sales in the price-sensitive Indian market.

Future Plans

- The company plans to establish local operations in India either by partnering with a local company or by setting up its own manufacturing / development unit, potentially combined with imports of specific components.
- The company expects to further grow in India, underpinned by a growing commercial fleet market for two-wheelers especially for last mile delivery/urban freight services.
- LHS also sees opportunities across the supply chain in the battery, EV component and charging infrastructure segments including the machinery and equipment needed for establishing manufacturing plants, training and provision of skilled workforce etc.

10. Appendices

10.1 Vehicle Types in India

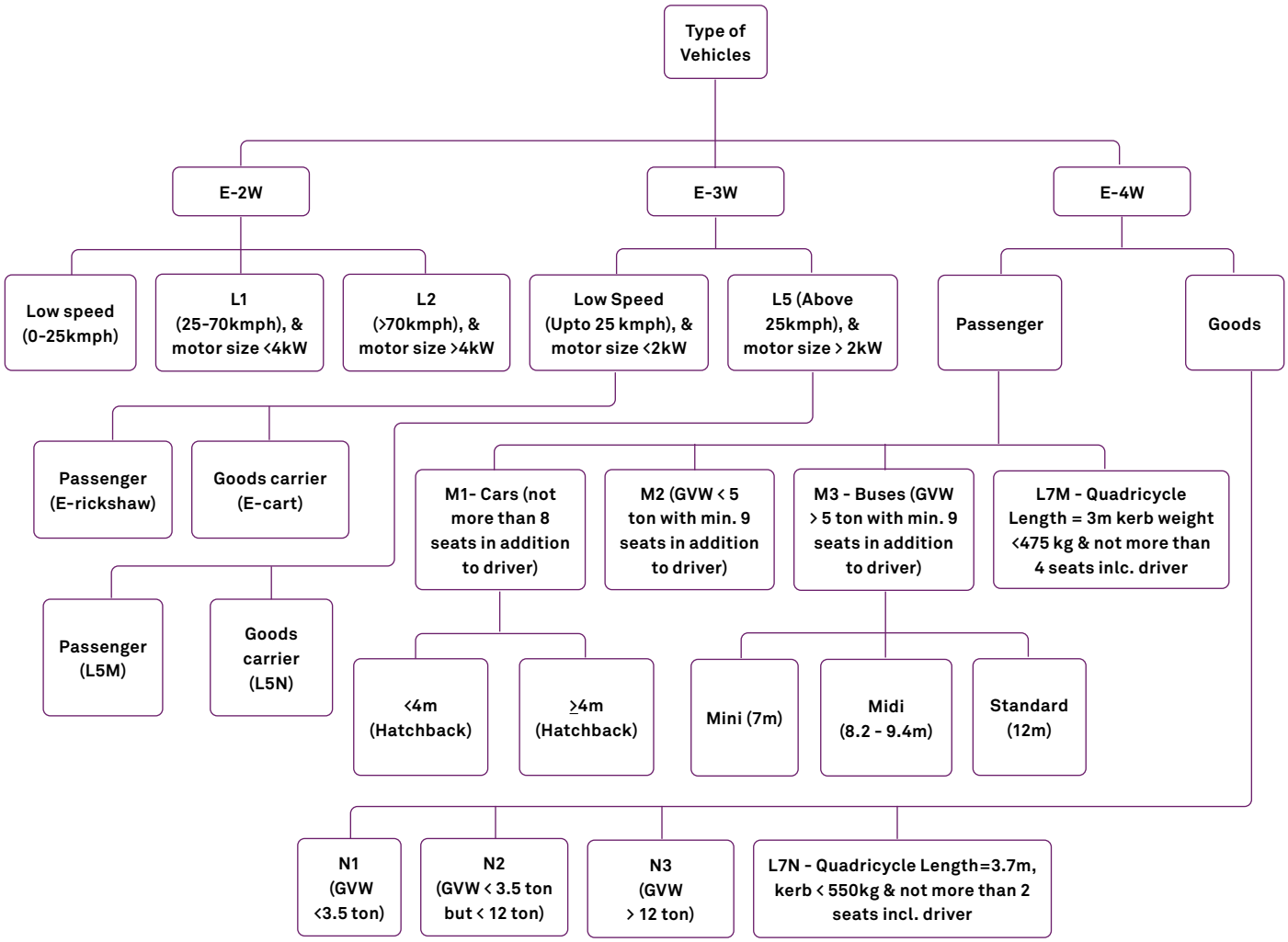

Figure 17 EV classification used by Gov. of India based on Central Motor Vehicles Rules (CMVR), 1989

10.2 Private Investment Landscape in electric two-wheeler segment in India

Date	Company name	Company type	Deal type	Investor(s)	Deal value ($ Mn)
Mar-20	Bounce	Bike & scooter rental	Equity	InnoVen Capital	7
Nov-19	Ampere Vehicles	Manufacturer	Equity	Greaves Cotton	8.4
Nov-19	Vogo	Bike rental	Equity	Matrix Partners, Stellaris Venture Partners, Kalaari Capital	4.0
Nov-19	Yulu	Bicycle & e-scooter rental	Equity	Bajaj Auto	8.0
Nov-19	Zypp	E-scooter sharing	Equity	Indian Angel Network	2.1
Oct-19	Tork Motors	Manufacturer	Equity	Ratan Tata	
Aug-19	Rapido	Bike taxi aggregator	Equity	Westbridge Capital, BAce Fund, Astrend India Investment and Nexus Venture Partners	54.9
Jul-19	Ampere Vehicles	Manufacturer	Equity	Greaves Cotton	5.6
Jul-19	Pure EV	Manufacturer	Equity	V.C. Nannapaneni, Chairman and Managing Director, Natco Pharma	35
Jul-19	BattRE	Manufacturer	Equity	Gajendra Chandel, Former President, Tata Motors Ltd.	Undisclosed
Jul-19	Bounce	Bike & scooter rental	Debt	BACQ Acquisitions Pvt Ltd.	1.5
Jun-19	Bounce	Bike & scooter rental	Equity	B Capital, Falcon Edge, Accel Growth Fund, Maverick, Qualcomm	72.0
Jun-19	Tork Motors	Manufacturer	Equity	Bharat Forge	4.3
Jun-19	Vogo	Bike rental	Debt	Alteria Capital	3.6
Jun-19	Vogo	Bike rental	Equity	Ananth Narayanan, K Ganesh, Srini Anumolu, Manish Vij	1.1
May-19	Ather Energy	Manufacturer	Equity	Sachin Bansal	32.0
May-19	Ather Energy	Manufacturer	Debt	InnoVen Capital	8.0
Apr-19	Bounce	Bike & scooter rental	Debt	InnoVen Capital	3.0
Mar-19	Bounce	Bike & scooter rental	Debt	Sachin Bansal	3.0
Mar-19	Vogo	Bike rental	Debt	Sachin Bansal	3.0
Jan-19	Rapido	Bike taxi aggregator	Equity	Integrated Capital, Skycatchr, AdvantEdge, Astrac Ventures	10.0

Table 17 Key Investment deals in e2W space in India (FY2019-20) (Source: JMK Research, May 2020)

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Connected Places Catapult
cp.catapult.org.uk
CPCatapult
linkedin.com/company/cpcatapult
info@cp.catapult.org.uk

Energy Systems Catapult
es.catapult.org.uk
ESCatapult
linkedin.com/company/energy-systems-catapult
info@es.catapult.org.uk

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CATAPULT Energy Systems