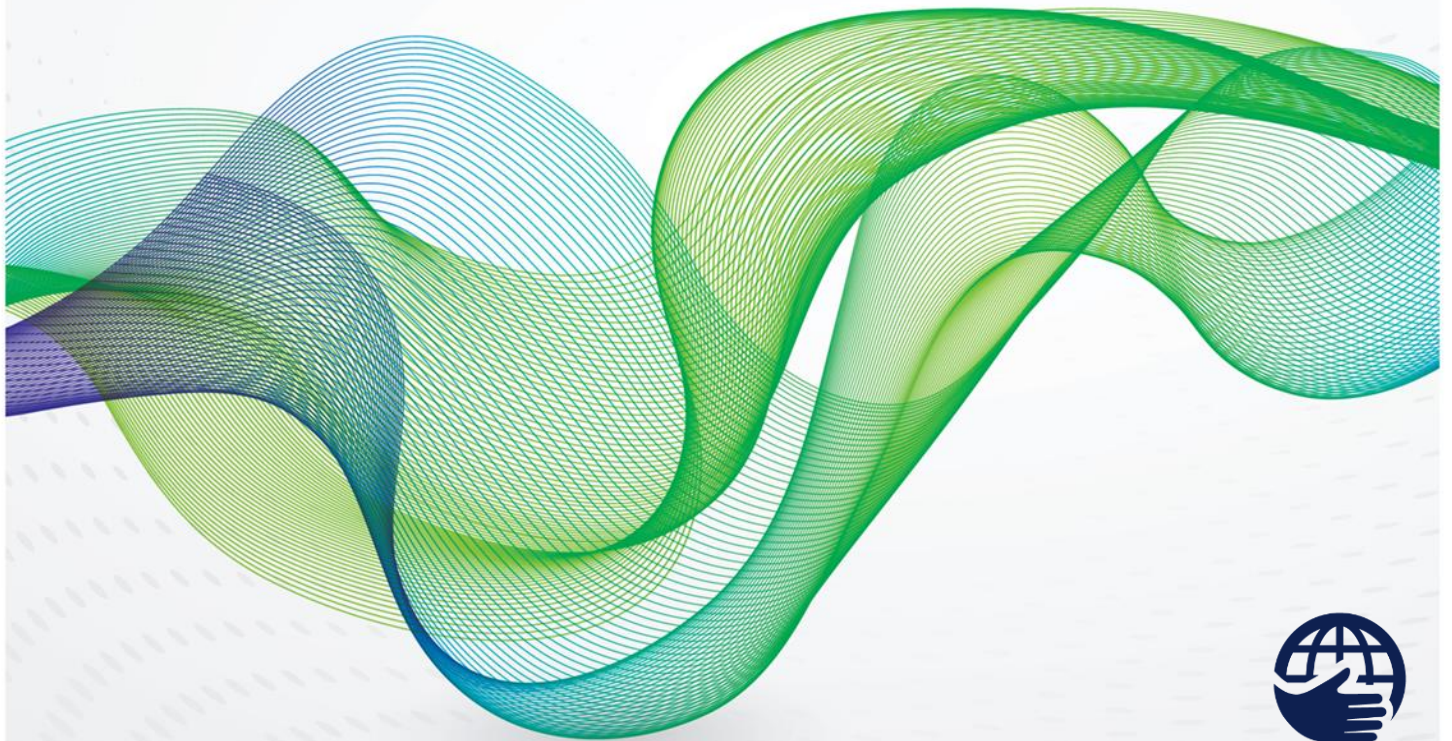


May 2022

India's Mass-Market Clean Mobility Initiatives and its Unique, Customized Business Models for Light Electric Vehicles



Energy
Transition

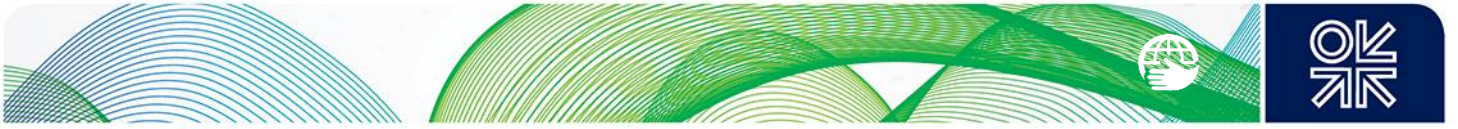


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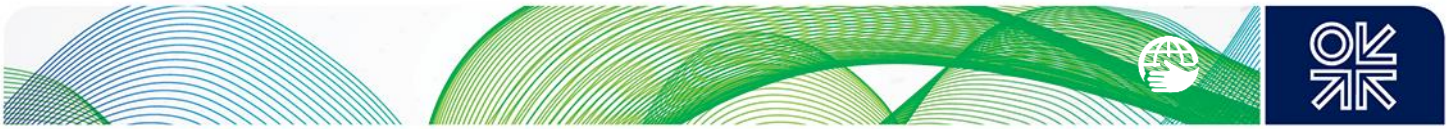
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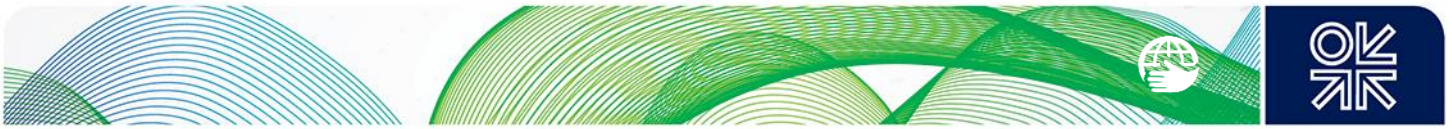


Executive Summary

- The global energy transition initiative currently has two mainstream business-to-consumer (B2C) clean technologies that require out-of-pocket payments from retail customers: rooftop solar systems and electric vehicles. Most of the other decarbonization investments in widespread use do not involve a retail consumer's decision to purchase, and hence individual affordability considerations are not a major determinant in their adoption (an exception would be energy-efficient retrofits of residential buildings).¹ In a market such as India, where the per capita GDP is less than US\$2,000 per annum, and annual per capita electricity consumption is 1,100kWh, or one quarter of the global average, the **affordability** of any retail B2C clean technology is of paramount consideration in terms of its widespread adoption in the retail market segment.
- Electric mobility is a purely B2C technology, with a 25–30 per cent higher upfront cost than a diesel or petrol vehicle in India, principally due to the battery cost. Hence, ensuring its broad, voluntary adoption is a major challenge in a diverse and income-segmented consumer market such as India's. Unlike in developed economies, India will not kick-start its electric mobility journey by deploying premium electric passenger cars. Instead, from a government's perspective, it is more effective to focus on electrifying vehicles with the highest demand and utility, such as two-wheelers and three-wheelers.
- The government of India subsidizes a support scheme for the adoption of electric mobility. Its acronym is 'FAME', or Faster Adoption and Manufacturing of Hybrid and Electric Vehicles, and the first phase ran from 2015 to 2019; it is now in the second phase, which will last up to 2024. Important lessons were learned² from FAME I, following an independent evaluation of the programme. These insights were incorporated in the updated FAME II, which is the present support programme. The scheme broadly provides capital subsidies to eligible consumers and manufacturers, and also to investors in the public electric vehicle charging network. The focus has shifted from subsidizing the purchase to subsidizing usage and clean vehicle-kilometres travelled.
- If India is to achieve its targeted transition to 30 per cent electric mobility by 2030 (compared to 1 per cent electric mobility today), then hundreds of millions of low-income consumers must perceive greater overall savings from purchasing an electric vehicle (EV) despite its relatively higher upfront cost compared to a familiar internal combustion engine (ICE) vehicle.
- The Indian government's overall EV market development programme consists of a full spectrum of clean mobility initiatives and subsidy schemes (spanning electric buses and all vehicle segments, as well as support to manufacturing EVs and funding for EV-charging stations, as well as a few rural transport initiatives). **This paper focuses only on the fast-growing urban battery-powered electric two-wheeler (2W) and three-wheeler (3W) market.** It highlights the market's response to the 'budget-priced segment' of the light EV market.
- Electric mobility in light vehicles, particularly since 2020, has attracted a substantial market response from the private sector in terms of innovation and the development of consumer-centric business models, such as manual battery swapping. As a result, budget EVs (2W and 3W) are today becoming more affordable to low-income consumers. **The scope of this paper includes a closer examination of how the private sector in India has catalysed fast growth in this area. As a result, the Indian clean mobility market is seeing a distinctive 'budget electric mobility' segment for low-income consumers.**

¹ Examples of non-retail, or B2B (business to business), zero-carbon technologies include onshore and offshore windfarms, large-scale solar parks or floating solar projects.

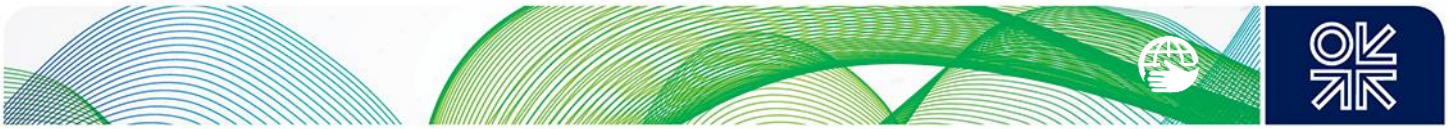
² <https://pib.gov.in/PressReleasePage.aspx?PRID=1577880>



- Four forces are driving India's determination to achieve a high penetration of urban³ electric mobility: (i) rapid urbanization and the need to deliver affordable and sustainable solutions to complete tens of millions of daily short trips (on average 12–15 km); (ii) improving energy security and trade balance by reducing the oil import bill; (iii) the imperative to reduce air pollution as a serious public health issue, particularly in major cities; and (iv) ambitious greenhouse gas emission reduction goals.
- The public EV-charging network has been delayed for various reasons and will be unable, at least in the near future in most states, to offer a variety of public charging services to diverse vehicles at the scale required. Currently, the light EV market is growing despite minimal reliance on public charging facilities. The shortage of public EV-charging points is likely to persist for the next few years and is linked to the need for many state-owned and financially struggling electricity distribution companies to upgrade the distribution network infrastructure. The market has come up with alternative solutions so that customers can either charge their light EVs at home, if the power supply is reliable enough, or in semi-public places such as office car parks. Other emerging options include charging only the electric two-wheeler (E2W) or electric three-wheeler (E3W) batteries at home, or subscribing to a battery leasing service for the E2Ws and E3Ws.
- Analysis has shown that the recommended approach for India's e-mobility roadmap is first to electrify commercial 2W and 3W vehicles, followed by commercial or fleet 4W vehicles operated by ride-hailing services. Commercial EVs and ride-hailing passenger cars, which all generally travel between 100 and 200 km per day, have the advantage of maximizing clean kilometres travelled, as well as 'sharing capacity' because one commercial delivery vehicle may keep ten of its customers' vehicles off the road. Electrification of more public buses operated by state transport agencies, and private E4W passenger vehicles, should follow these early high-priority early adopters as the costs of batteries and technologies fall.⁴ The most common mode of personal transport in India, accounting for more than 80 per cent of vehicles, are privately owned 2Ws, in other words, those not used for commercial deliveries or as bike taxis. These private trips are also a candidate for early conversion to electric mobility, provided the distance travelled per day is sufficient to generate financial savings from the petrol or diesel purchases avoided.
- The most affordable model of privately owned E2W (costing the equivalent of around \$800) has been achieved by separating the battery, which is leased, from the body of the vehicle, which is owned. This 'separate battery' model, also known as the Battery-as-a-Service (BaaS) approach is also of interest for E2W and E3W light commercial vehicles. Additionally, given that most trips are short and traffic speeds at rush hour can sometimes be as slow as 17 km/hr, it emerges that there is a budget market segment that can be well-served by batteries that have a short range (around 50 km) and a top vehicle speed of 25 km/hr. The government has further removed entry barriers for this segment by withdrawing the requirement to register and insure vehicles in the 'low-speed E2W' category. Such vehicles can manage to run as delivery vehicles for 100 km a day with a single battery swap.
- Another key lesson emerging from the first two years of light EV market experience is that there is a high degree of segmentation among customers of EVs, particularly among E2Ws. Some

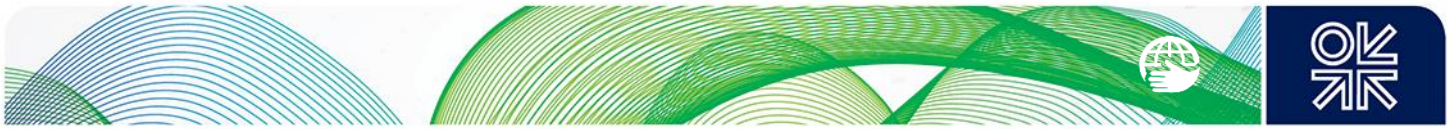
³ According to the census, Tier 2 cities in India have a population of 50 000 to 100 000 and Tier 3 cities have a population of 20 000 to 50 000. Recent studies show that the fastest growth in 2W electric vehicle purchases is occurring in Tier 2 and Tier 3 cities in India. Further details on these findings are here https://www.business-standard.com/article/companies/small-indian-towns-overtaking-big-cities-on-ev-ride-shows-ceew-report-122042601063_1.html published 27 April 2022 (accessed on 5 May 2022).

⁴ Arora, N., Raman, A. (2019). Beyond Nagpur: The Promise of Electric Mobility. Lessons from India's First Multimodal E-Mobility Project. Ola Mobility Institute. <https://olawebcdn.com/ola-institute/nagpur-report.pdf>



are not prepared to drive EVs unless the full responsibility of owning the battery is removed from them through a leasing arrangement. Others want the battery to be detachable but want to maintain full control and ownership of it. Still others do not want the battery to be removable. Vehicle manufacturers have been understanding this diverse user base and have been building a range of E2Ws accordingly. Each customer segment must have their needs met in order to see growth in the light EV market.

- Some in the battery industry and EV manufacturing industry have concerns about a current government proposal to standardize swappable batteries for light vehicles, particularly companies that have already entered the business and invented vehicle designs and battery management systems of their own. The government believes that standardization will help to grow the market by enabling economies of scale and drive down the cost of the battery, while ensuring safety standards in Indian conditions (mainly high temperatures and occasionally poor roads). The government's proposal may also be driven by the belief that a mandated set of battery specifications would avoid market fragmentation in the technology, which could lead to much greater market entry at all stages (battery manufacturing, vehicle manufacturing, battery-swapping stations, software and app development). This could ensure that costs fall faster and, in turn, increase the adoption of EVs. However, calculations show that the current pricing of BaaS, through battery subscriptions for swapping services, is still too high to be affordable to a vast majority of the mass market. Despite all efforts to make access to batteries affordable, some customers (delivery and ride-hailing drivers) are still paying a high share of their income for battery-swapping services. For the Indian mass market to adopt widespread e-mobility at an accelerated pace, battery costs will likely have to fall to about half of their current levels.

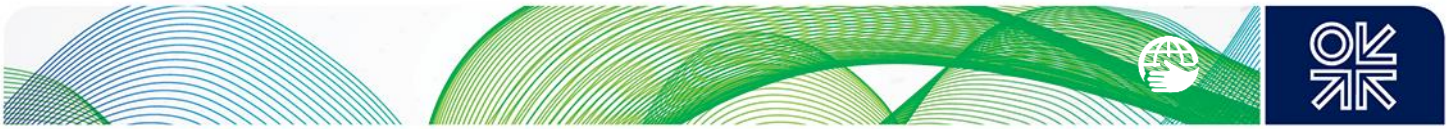


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1. Overview

The objective of this paper is to discuss India's efforts in catalysing an urban light EV market that sustainably meets the mobility needs of the low-income segments of its urban population. The urban population is set to grow substantially in the coming decade, and workable clean transport solutions are urgently needed if electric mobility is to go mainstream. India has an entrenched ICE vehicle manufacturing tradition, and today 99 per cent of the vehicle market still runs on petrol, diesel, and compressed natural gas (CNG). This paper looks at some of the main structural challenges arising in the proposed shift to low-budget e-mobility.⁵ These include low affordability even when it comes to the purchase of small and light-duty EVs, such as 2Ws and 3Ws, despite generous upfront subsidies from the government. Also, many states in India still have a weak electrical distribution network infrastructure that does not provide a reliable 24/7 power supply for on-demand EV-charging at home. There are also various shared living situations in multigenerational families, where separate electricity meters would be required for one or two family members' EVs, but the electric utility is not financially equipped to provide these additional meters to homes or to parking spaces in apartment buildings within a short time. All these factors create potential practical obstacles to attracting investment in a personal light EV, such as a 2W with wired charging at a home parking space.

On the positive side, there have been some recent EV market boosters, in particular an active programme of generous government subsidies to promote electric vehicles. There is also the high cost of petrol and diesel, particularly since 2020, which is causing people to actively search for alternative, affordable mobility solutions. These behavioural changes may otherwise have taken longer under a business-as-usual approach to promoting EVs.

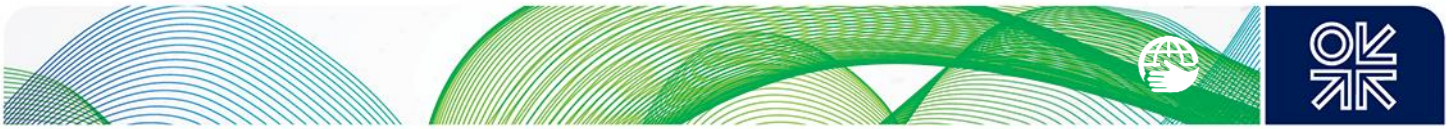
The e-mobility transition is not an easy proposition in a complex and huge market such as India's, in which 22.7 million ICE vehicles of various types (from passenger cars to buses, tractors, heavy-duty and light-duty trucks, 2Ws and 3Ws) were manufactured and four million were exported in 2021.⁶ The e-mobility transition lessons from Europe, the US, and even China are not relevant to the Indian context given the vastly different customer segments, needs, and budgets in India. International markets, which are mainly focused on four-wheel (4W) passenger cars and some two-wheelers (2W), are far simpler to measure, evaluate, and promote than the Indian situation. The complexities of the Indian vehicle market, and the multiple considerations that must be taken into account, including building special types of EVs with features that currently do not exist in order to meet the requirements of multiple consumer categories, are explained in detail below.

The remainder of this paper is divided into four parts. **Part Two** will look at the context of Urban Mobility in India. Specifically, it will discuss a number of factors that contributed to the recent surge in consumers' interest in light EVs at the budget end of the market in India.

Part Three reviews the budget end of the light EV market in India and introduces the battery swapping model. It provides an overview of the nascent mass-market EVs that have only been available for commercial purchase (through waiting lists) since 2020 and mainly since 2021, initially in limited

⁵ Demand from owners and sellers for EV-charging points, even at present limited to one per cent of EV penetration, cannot be met. This is due to the very limited ability of distribution utilities to provide the requested increases to the customers' contracted load, often due to overloaded distribution transformers at the network's last mile. The business model for private investment in EV charging, and the commercial proposition of how much to charge the final customer, is also still evolving. Public EV charging has been de-licensed and many states have announced favourable (low) tariffs for the charging point owner, but there are other infrastructure costs that must be recovered and the question is how much of this will come from the customer and how much from government subsidies.

⁶<https://www.investindia.gov.in/sector/automobile#:~:text=India's%20annual%20production%20in%20FY.by%20small%20and%20mid-sized%20cars> (accessed on 17 April 2022).



numbers.⁷ It introduces and looks in more detail at the nomenclature and types of vehicles which are in most widespread use in India, currently in ICE form, and their respective use cases.⁸ In addition, it discusses what types of business models would be needed for their shift from today's ICE versions to EVs. Specifically, the paper looks at what types of convenience and money-saving features would need to be included in new EVs in order to persuade value-conscious and financially struggling customers (who number around 900 million) that it makes financial sense to buy them. This is relevant given the wide range of customer needs, budgets and circumstances in India.⁹ This part of the paper also examines the details of the battery-swapping business model and refers to the results of an in-depth study¹⁰ consisting of a detailed, rigorous analysis of the Total Cost of Ownership (TCO) of light EVs depending on various use cases in India. Given very different rates of usage, such as daily distance travelled or clean vehicle-kilometres in each use case, there is a different result in terms of operating cost for identical vehicles, depending on who is driving it and for what purpose.¹¹

Part Four discusses the difference between the energy operator (EO)'s swapping station charging service and the charging point service of an EV-charging network operator. It explains why the EO swapping station services are being set up much faster than the EV-charging point network. **Part Five** concludes the paper with a look at the Way Forward, and presents some thoughts on how India is preparing for an inclusive uptake of e-vehicles, focusing particularly on approaches that will help to achieve increased affordability for the budget segment of the clean mobility market.

2. The context of mobility in urban India

India's urban population is likely to be nearly double by 2030 due to rural-urban migration. In addition to the numerous other sustainability challenges that this will pose, there is a pressing need to find sustainable urban mobility solutions to how hundreds of millions of daily short trips (on average 12–15 km) can be completed emissions-free within its large cities.

With private vehicle ownership (ICE cars and ICE 2Ws) growing at a 10 per cent compound annual growth rate, India would need to add a lane to every national highway every three years to

⁷ Legacy ICE vehicle manufacturers have largely stayed out of the e-vehicle market until recently. Start-ups which were experts in software, design and in solving IT challenges for such vehicles, such as GPS tracking of the vehicle location, mobile apps and storage of battery data in the cloud etc., had difficulty in securing investor funding to start manufacturing operations.

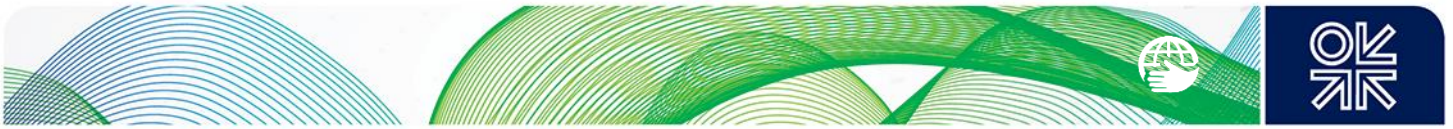
⁸ Two-wheelers are mostly for personal or commercial (such as deliveries or bike taxis) use, while three-wheelers are always commercial and are used to transport passengers or goods.

⁹ From around 2015 onwards, many 3Ws in cities such as Delhi had converted to running on CNG as the fuel of choice, since it was clean/less polluting, and also because CNG was subsidized. Today, new 3W buyers must consider whether CNG or electric is the better fuel choice. Three-wheelers, which commercially transport passengers or goods, come in two variants, for high speed and low speed, with different payload capacities (up to 300 kg and up to 600 kg). There are also different models, with an ability to handle different types of terrain as required for different geographical sub-markets in the country (photos are in Part One of this paper). EVs for commercial use will also require in-built communications capabilities, such as vehicle tracking, mobile app connectivity, and battery data to the cloud enabling the rider to check remaining battery charge. Furthermore, Niti Aayog, the government think tank, recommends that EV supply equipment should have the capability to communicate with EVs (smart charging).

(See the NITI Aayog Handbook of Electric Vehicle Charging Infrastructure Implementation. Version 1 <https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pdf> page 15, reference to 'dumb charging').

¹⁰ Dash, N. and Bandivadekar, A. (November 2021). Cost Comparison of battery swapping, point charging, and ICE two-wheelers in India. The International Council on Clean Transport. <https://theicct.org/wp-content/uploads/2021/12/cost-compare-india-ice-2ws-ldvs-nov21.pdf>

¹¹ The study also considers waiting times for charging, which translate into lost money for gig workers, which is not a factor with ICE vehicles, for example. One way to overcome this and enhance the attractiveness of e-vehicles is, for example, to offer a manual battery-swapping business model. The study undertakes a detailed costed comparison of ICE vehicles with two types of e-vehicles that use two different charging technologies, in other words battery-swapping versus point-charging, and it comes to conclusions about which one is right for which particular use.



accommodate these new vehicles, reinforcing the need for shared mobility solutions.¹² As per the Road Transport Year Book, 230 million vehicles were moving on Indian roads in 2016 out of which 86 per cent were private vehicles,¹³ mostly 2Ws.

Another top priority of the Indian government is to achieve energy security by reducing high fuel import bills. In 2019, an Indian think tank, The Energy and Resources Institute (TERI), estimated that the transport sector accounted for about twenty-four per cent of commercial energy consumption in the country, leading to a large share of the import bill.¹⁴ Notably, India was able to achieve a long-desired milestone of exceeding \$400 billion of merchandise exports in 2021, but nevertheless the trade deficit increased, because a large share (more than \$100 billion) of the foreign exchange earnings had to be paid out for fossil fuel imports whose prices have sharply increased since Q3 2021. Reducing dependency on imported oil and gas is a high priority for the government.

Air pollution from diesel and petrol-powered transportation in cities is another major concern. India's Centre for Science and the Environment has estimated that pollution is responsible for a high percentage of premature deaths, making it a public health emergency. Air pollution is worsened by traffic congestion; at peak rush hour in some of the major metro cities (with a population or more than 10 million) vehicle speeds may fall as low as 17 km/hr.¹⁵ This intensifies the localized concentration of harmful particulates from exhaust emissions while also causing excessive fuel consumption that adds to the import burden, in addition to delays and loss of productivity.

At Glasgow's COP26 in November 2021, India announced increased climate commitments that included, among other things, a 1 billion tonne reduction in CO₂ emissions by 2030, and a 40 per cent reduction in the energy intensity of its economy relative to 2005. The urban mobility sector is a major contributor to this goal.

Key factors impacting electric mobility

Since 2020, Indian consumers have started paying increased attention to EVs. The motivations favouring public attention for e-mobility options include:

- prolonged periods of very high prices of diesel and petrol in the country;¹⁶
- an unanticipated boom in e-commerce deliveries during the pandemic, where sellers had to absorb most of the skyrocketing fuel prices on last-mile delivery costs in order to retain customers, and
- an active programme of generous government subsidies to promote electric vehicles,¹⁷ both from the supply side (to incentivize localized manufacturing of both vehicles and batteries, and also partial payments towards the installation of an EV-charging network) and from the demand side (cost-sharing grants to lower the upfront purchase cost and increase affordability).

¹² Enabling the Transition to Electric Mobility in India. FICCI Smart Mobility Conference (20 November 2017) https://rmi.org/wp-content/uploads/2017/11/report_electric_mobility_india_FICCI_RMI.pdf

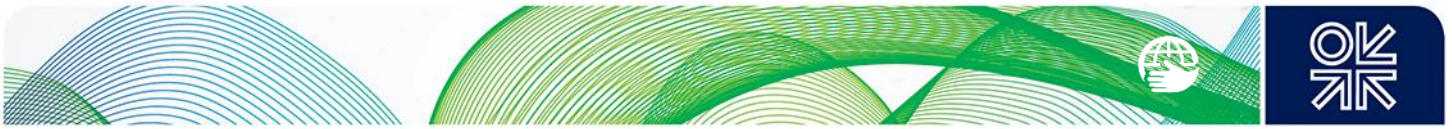
¹³ <https://www.teriin.org/article/clearing-haze-shared-mobility>

¹⁴ <https://www.teriin.org/article/clearing-haze-shared-mobility>

¹⁵ <https://indianexpress.com/article/technology/opinion-technology/how-shared-electric-mobility-can-benefit-india-5593408/>

¹⁶ The central government imports crude oil for Indian refineries; 90 per cent is then marketed to the public through government-owned oil marketing firms, sold at prices which include an excise tax and a 'cess' that is collected by the central government. Each state then adds its own fuel taxes that are set according to its specific policies and funding requirements; this is why petrol and diesel pump prices differ across states in India.

¹⁷ The electricity sector in India is governed by policies made at the state level and by central government. State EV policies have had a large role to play in the growth of EV adoption as some states have added their own subsidies in addition to those of central government. An uneven pattern of EV adoption is emerging across states and categories which requires further research. Out of 28 states, so far 18 states in India have already notified final EV policies, and these states are the ones that have recorded the highest EV sales. At present three more states—Bihar, Haryana and Punjab—have draft EV policies that are expected to be passed soon.



The biggest factor by far driving the search for alternative transport solutions is the petrol and diesel price, which has been breaking new records for nearly two years. At the start of 2020, before the pandemic, the average nationwide retail petrol price at the pump was INR 69 per litre (just under \$1); by mid-2021¹⁸ it had crossed the psychological threshold of INR 100 per litre and on 19 April 2022, it stood at INR 112 (just under \$1.50).

Indian retail pump prices for most of 2020 and 2021 bore little relationship to global crude oil prices due to taxes. This was deliberate, resulting from the government's decision to impose high taxes on petrol and diesel and compensate for other sources of government revenue that had dried up with the loss of economic activity. Figure 1 shows the high level of taxes that the central and state governments imposed on imported liquid fuels as far back as the first lockdown of April/May 2020. This was in order to meet public expenditure during the pandemic, as customary sources of tax revenue linked to industrial activity had all but disappeared.

Figure 1: Share of taxes in the retail sales price of petrol and diesel (Delhi, June 2020)



Source: <https://theprint.in/economy/petrol-at-rs-100-litre-why-theres-more-to-fuel-price-hikes-than-just-global-oil-cost/680701/>

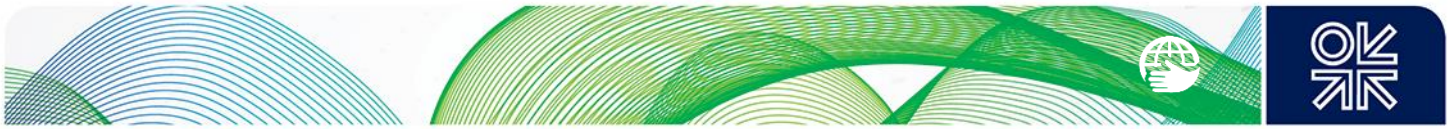
In an October 2021 interview (just after India had finished administering one billion free Covid 19 vaccines), the Indian oil minister stated that:

additional [fuel] taxes have paid for vaccines, free meals three times a day to 900 million [poor and 'suddenly poor'] people, and free cooking gas [cylinders] to 80 million households for over a year.¹⁹

In short, the public perception is that there will be no relief from high excise duties and state VAT levies on petrol and diesel any time soon. Therefore, consideration of EVs as an alternative to ICE vehicles, and how to afford them, becomes a matter of increasing awareness and urgency. This was not the case prior to the pandemic and the resultant record high fuel prices in the country.

¹⁸ https://m.economictimes.com/industry/energy/oil-gas/petrol-prices-in-delhi-surge-over-rs-30-per-litre-since-april-last-year/amp_articleshow/84406884.cms (accessed on 19 April 2022).

¹⁹ India could not afford any kind of across-the-board stimulus payments seen in Europe and the US; its pandemic response was instead to focus government payments on social protection for a majority of the people who were previously poor and eligible for subsidies for a long time, and also as many as possible of those from the middle class who were not previously poor but suddenly lost their employment and incomes overnight. Reference to the interview with the oil minister: <https://www.livemint.com/news/india/petrol-price-is-up-by-rs-36-a-litre-diesel-by-rs-26-5-in-just-18-months-11634981493401.html> (This article from October 2021 was accessed on 15 April 2022)



Apart from high fuel prices that are creating an interest in EVs, the pandemic also brought about a boom in last-mile delivery and transportation needs for e-commerce deliveries.²⁰ This has been a key factor in driving electrification in the 3Ws segment of the transport sector (discussed below).

What is the government's role with respect to supporting EV market growth?

Unlike China, India cannot afford to subsidize the development of the entire EV industry. Long before the pandemic, the government had launched a subsidy programme (FAME I) in 2015 to support electric mobility, focusing primarily on reducing the purchase cost through grants. However, it had limited impact since the supply of affordable EVs available for people to buy was negligible. Subsequently, following an independent evaluation of the programme, the government concluded that it should subsidize usage (clean vehicle-kilometres travelled) instead of the purchase. Hence FAME II changed its focus to vehicles with increased battery range (80 km or more). In the light-vehicle segment, this applied mostly to high-speed 2Ws that required registration under the Motor Vehicles Act. The FAME II subsidies were also available for a range of 2Ws, 3Ws, and commercial (fleet and ride-hailing) 4Ws.

Under FAME II, it also rapidly emerged that there was a strong need to support the creation of a public EV-charging network, without which most buyers were not willing to invest in EVs. This applied particularly to passenger cars (4W) that were no longer subsidized directly, but nevertheless required a charging network to combat range anxiety. The second phase of the FAME programme has now been extended from 2019 to 2024. So far, FAME has fallen far short of the original targets and there are still substantial unspent funds.²¹

FAME II includes demand-side grants for the purchase of eligible 2W or 3W high-speed vehicles with a minimum 80 km range,²² as well as supply-side and localization grants for the domestic manufacturing of all vehicle components and batteries in an effort to increase affordability. FAME II also provides grants to investors in EV-charging points or networks. It is important to note that the Indian states have the final say on state-level electricity policies that will apply within their territory. So far 18 out of 28 states have announced EV policies. Some states, such as the National Capital Territory of Delhi, have been at the forefront of electric mobility and have issued numerous policies and incentives over and above the central government's FAME support. Delhi also has the advantage of having an electricity distribution network that was largely rebuilt in the past 15 years or so, after privatization.²³

Charging points and networks

The limitations of EV-charging points and networks have been highlighted in a number of recent studies. In a recent study, the World Bank²⁴ notes that:

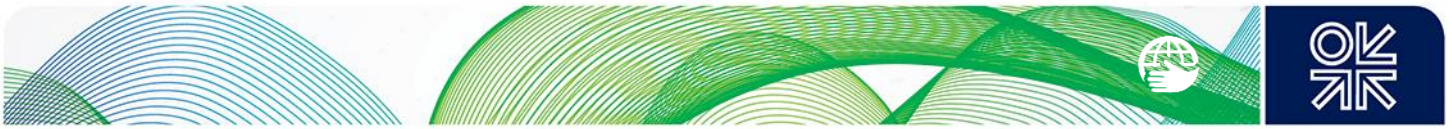
²⁰ Until now, most e-commerce giants have been working with gig-work 'delivery partners' who bring their own ICE 2Ws and do last-mile package deliveries; in most cases the e-commerce companies reimburse the delivery partners for the fuel. However, there is an increasing move towards engaging with 'contract carriers' to handle the logistics, so that the gig workers move to being employed by the contract carriers; the next trend is for e-commerce companies to invest in their own e-vehicle fleets. Manufacturing companies cannot produce e-delivery vehicles fast enough to meet the demands from e-commerce giants.

²¹ Many states also have their own fiscal incentives in addition to the central government's FAME programme, and Delhi is the most advanced and generous state in terms of promoting e-vehicles.

²² <https://auto.hindustantimes.com/auto/news/everything-about-new-fame-ii-subsidy-why-e-two-wheelers-are-becoming-cheaper-41623904715571.html> (accessed on 20 April 2022).

²³ It is fair to say that Delhi is leading on the nation's EV progress. Other states are mostly still operating electricity distribution networks that are managed by state governments, and these networks are still in the early stages of being upgraded with funds from a special loss-reduction programme that is funded by the Ministry of Power. Around 18 Indian states have nevertheless introduced ambitious EV policies, and Karnataka is a leader among them. Access to suitable land for charging points is a constraint to public EV charging; the central government has urged states and local governments to make public land available at very low or no cost on a revenue-sharing model. This requires a great deal of coordination and transparency, and will therefore take time.

²⁴ Gupta, A., Gencer, D., Saraswat, K. and Mittal, R. (April 2021). *Electric Mobility in India: Accelerating Implementation*. The World Bank Group. <https://openknowledge.worldbank.org/bitstream/handle/10986/35655/Electric-Mobility-in-India-Accelerating-Implementation.pdf?sequence=1&isAllowed=y>



While several states are promoting use of electric vehicles, only a few DISCOMs [distribution companies] have undertaken studies to assess impacts of EV charging on the electricity network.

The study also points out that the distribution company should carry out the low-voltage network upgrades, but in the case of EV-charging points, the prospective investor is being asked to make the investments in additional transformer capacity. This is clearly a high-entry cost barrier that is difficult to recover through charging revenues in a nascent market.

Various studies, including TERI (2019) and World Bank (2021) and the Handbook of Electric Vehicle Charging Infrastructure Implementation (NITI Aayog 2020) all draw attention to the importance of the electricity infrastructure having the ability to bear the additional load.²⁵ Expenditure on grid augmentation will be needed as part of boosting the adoption of EVs, and budgets will have to be identified to fund and coordinate these upgrades.

Targets for greater penetration of EVs all contain built-in assumptions for satisfactory levels of charging services to come from the grid, whether through home charging or semi-public charging (at an office or apartment complex, which is a shared arrangement but not open to the public), or in future at fully public EV-charging stations. It is no surprise that Delhi, with its three private distribution utilities and one of the newest electricity grids in the country, also happens to be the state which is most advanced in terms of EV policy, EV adoption, and generous state-funded financial incentives over and above those given by the central government. Delhi is able to leverage its modern distribution grid and its sophisticated, modern electricity distribution companies to forge ahead with its EV ambitions, which ultimately rest on the shoulders of the electricity providers.

3. E2Ws, E3Ws, and the battery-swapping model

Figure 2 illustrates an E2W for passenger or commercial use. Figures 3 and 4 show an E3W vehicle in an Indian context. The photos present a very limited selection of models, while in practice there are numerous configurations available that are suitable for different parts of the country and different market segments. After subsidies, the prices of E3Ws are around \$3,500 to \$4,500 equivalent.

E2W vehicles, depending on their features, battery capacity, top speed, etc., range from a minimum of about \$800 after subsidies, without battery ownership, to a high-end model of around \$2,300 equivalent after subsidies, with a powerful battery included.

There is usually a three-year, 1,000 cycle battery warranty for most basic 2W vehicles that come with the battery included.²⁶ Therefore, the cost of a new replacement battery (today around INR 60 000, equivalent to \$800, same as the chassis) would have to be incurred again after a few years by the customer who has purchased the full vehicle (battery plus body).

Since the warranty covers 1,000 cycles, it follows that for intensive, for example, commercial, users, the battery replacement cost would come as early as 18 months after purchase assuming the battery is charged twice a day. This prospect of a battery replacement obligation is not attractive to most low-income users. The expectation of manufacturers and the government is that future battery replacement costs will be lower than they are today if battery prices continue to decline as per current trends.

²⁵ An impact assessment study conducted by a modern, privatized Delhi electric utility, BSES Yamuna Power Limited (BYPL), in 2019 showed that EV charging would not present a challenge in terms of additional load and peak load in the near future. The incorporation of well-planned Time-of-Use tariffs and smart-charging technologies can help. However, for the majority (60 out of 70) of India's stressed electric utilities that are owned and operated by state governments, these optimistic findings from a privatized and modernized utility such as BYPL in Delhi, would not be applicable. The bulk of India's state-run and cash-strapped utilities first need to undergo major network upgrades and reforms. The Power Finance Corporation, under the Ministry of Power, is currently operating a major funding initiative for all state-run utilities wishing to modernize on a results-based financing basis. A few state utilities have so far submitted their initial business plans, as required, in order to qualify for funding. Completion of the reform process for participating utilities may take 5–10 years.

²⁶ The warranty is for 2,000 cycles in the case of a commercial 3W vehicle.

A significant segment of the e-mobility target market are the ICE-driving e-commerce ‘delivery partners’. Delivery partners use their own ICE vehicles to earn money from large e-commerce companies. When users are given E2Ws for test drives, they are very positive about the upgraded, pollution- and noise-free driving experience. However, they are not interested in buying an EV, whether or not there is a subsidy, because of the battery replacement cost obligation.

A big market lesson is therefore that at least one distinct and large group of e-mobility 2W customers in India does not wish to be exposed to the battery replacement risk. They would prefer to keep to ICE vehicles or just to sell their services as a driver, with no outright ownership of vehicles at all, unless a solution is found to reduce costs and remove the battery replacement obligation.

Figure 2: An E2W in action and on display in the showroom



Figure 3: Left: E3Ws for cargo. Right: an E3W fully loaded with a fridge and washing machine

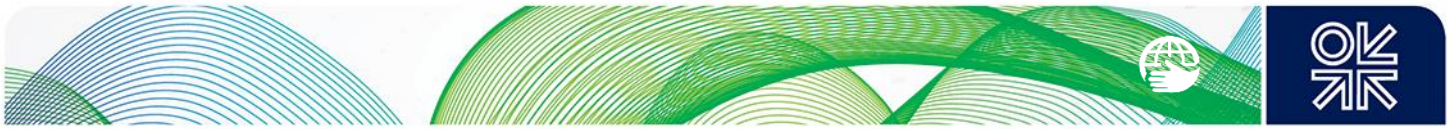


Figure 4: E3Ws for passengers. Left: two rear rows of seats facing each other. Right: one row of seats for three passengers and lots of leg room



Emerging lessons in the first two years of EV experience in India

Manufacturers are gradually learning and having to respond to customer needs and preferences in this very recent, untested and very segmented market. New business models unique to India are emerging









as solutions in response to challenges and consumer requirements. These include, but are not limited to, product distinctions such as ‘high-speed’ and ‘low-speed’ 2Ws.

As mentioned, one lesson drawn has been the reluctance of one segment of the customer base to take on the risk of battery management and the financial outlay for battery replacement after 1,000 cycles. That is the duration of the manufacturer’s warranty for 2Ws, while in the case of 3Ws, the warranty is for 2,000 cycles. E-mobility solution providers and designers have learned that there is a need to make vehicles with manually removable and swappable batteries for a large customer segment.

In contrast, another model, for a different type of customer segment, requires fixed batteries that cannot be removed at all and have an anti-theft feature. This is for EVs that will be plugged in and charged in a dedicated parking spot at home.

Many customers expect to be able to see battery data, indicating the state of the battery’s health and remaining charge, on a mobile app, so there is also a data requirement. For EVs that will be used by delivery partners, the vehicle must be enabled for GPS tracking. Customers also expect features such as USB ports and LED lamps when these are offered by a competitor. Figure 5 shows some features offered by one of the industry players.²⁷

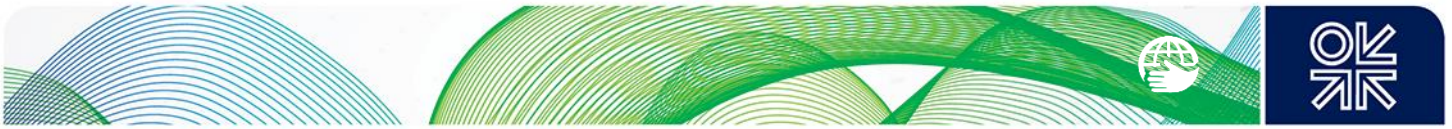
Figure 5: One example of an E3W and its features

 <p>Global Battery Technology</p> <p>Zero maintenance, lithium-ion battery with 3 years standard warranty & minimum 1 50 000 km of life.</p>	 <p>Cutting-edge Modular Design</p> <p>Space-frame architecture along with corrosion free modular SMC panels for dent free body, and easy repair or replacement.</p>	 <p>Cloud Based Mobility Platform (NEMO*)</p> <p>Remote monitoring of range, speed, location and more for Next Generation Mobility* and efficient utilisation of fleet.</p>
 <p>Zero Tail-pipe Emission</p> <p>Zero pollution and noiseless drive, making Treo environment friendly.</p>	 <p>Regenerative Braking System</p> <p>Kinetic energy generated on braking is fed back into the battery, thereby ensuring minimum wastage of energy.</p>	 <p>Quick Charging</p> <p>Charing the Treo is as simple as charging a mobile phone. Just 3 h 50 min to charge Treo and 2 h 30 min for Treo Yaari. A top up during lunch break can give you over 20** km of additional running. It can be charged anywhere as it comes with a portable charger and can be charged using a 15 A socket.</p>

What are low-speed vehicles and why are they popular?

The Indian Motor Vehicles Act does not apply to vehicles that have a maximum speed of 25 km/hr. The regulator treats these as bicycles, hence formal registration with a state government agency is not

²⁷ <https://www.mahindraelectric.com/vehicles/treo-electric-auto/>



required for low-speed EVs (just as with Lime/Bird electric scooters in Europe and the US). Registration, licensing and insurance is only mandatory for vehicles which can exceed 25 km/hr.

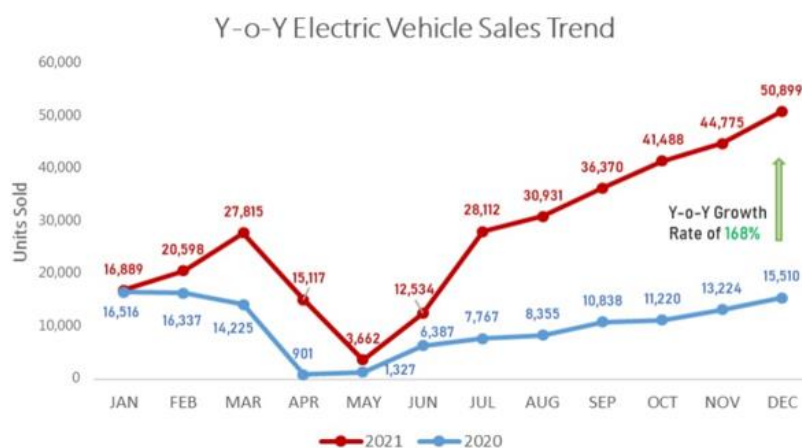
Many congested urban areas in India have low rush-hour traffic speeds, and the average journey length is between 10–15 km. Therefore, low-speed EVs, which avoid the registration process and thereby save on registration expenses and lost work time for the buyers, are the preferred choice for many customers. This includes young people commuting to university classes and also low-income people who need a vehicle for their livelihood or gig work. These groups are concerned about the continuously rising cost of petrol and diesel and are looking for solutions in the EV space, mainly to avoid the fuel expenses of ICE vehicles. Low-speed vehicles would suit their needs in terms of range and speed, dispensing with the need for registration or a mandatory license and insurance are all a plus.

The downside of purchasing such vehicles is that low-speed, unregistered vehicles do not qualify any longer for FAME II subsidies, mainly because of their low battery range of around 50 km. As mentioned earlier, FAME II has shifted the focus from incentivizing purchase to incentivizing usage. Longer-range batteries will result in more usage or clean kilometres travelled. Also, these two customer segments (students and gig workers) are averse to the financial requirement to purchase a new battery every 18 to 36 months, depending on their daily distance travelled and the resultant frequency of charging.

Figure 6 shows that 329,190 total EVs were sold in India in 2021. This represented a 168 per cent growth over 2020, which was the first year of significant, light EV market activity in India. Figure 7 attempts to make some estimates for the non-registered, or low-speed, E2W market given the change in fiscal incentives in 2021, when low-speed vehicles were no longer eligible for the FAME II subsidy. It shows a quick changeover to high-speed vehicles that have higher numbers of clean kilometres travelled per charge (usage is being subsidized). Registrations of high-speed E2Ws went from 27 per cent of total registrations in 2020 to 61 per cent in 2021. This clearly shows that the FAME II subsidies were directly influencing people's vehicle choices; when low-speed vehicles stopped being eligible for subsidies because their range was too low, customers quickly shifted to high-speed/high range vehicles in order to benefit from the subsidy.

Figure 6: Overall EV sales in 2020 and 2021

In 2021, 3,29,190 electric vehicles were sold in India, representing a 168 per cent increase over last year's sales of 1,22,607 units.



Source : Vahan Website and Telangana regional transport data portal

Source: [India's Electric Vehicle Sales Trend for 2021 • EVreporter](#) (accessed on 17 April 2022)

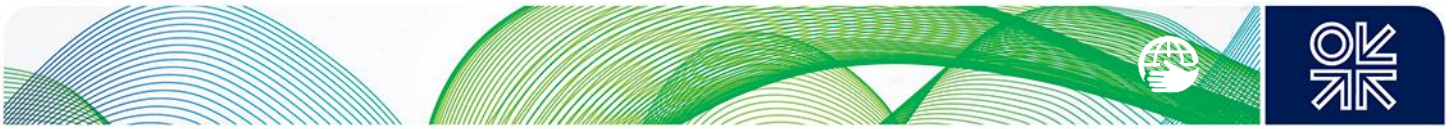
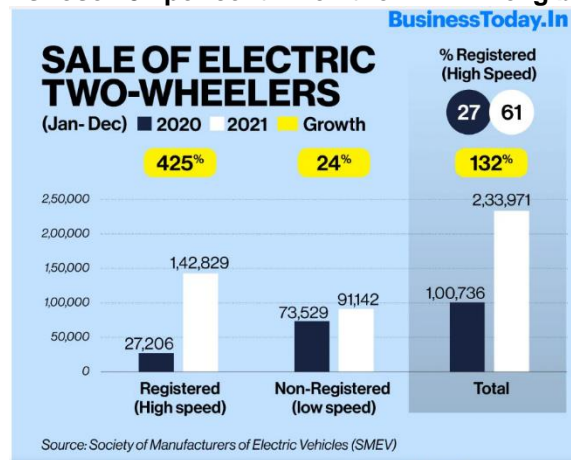


Figure 7: High-speed E2Ws rose 132 per cent when the FAME II eligibility criteria changed



Source: <https://www.businesstoday.in/latest/trends/story/electric-2w-sales-go-up-132-in-2021-2022-likely-to-see-6x-growth-smev-318269-2022-01-07> (accessed on 17 April 2022)

How does battery swapping help the Indian EV market?

The sellers and manufacturers have addressed the issue of the cost of needing to replace the battery, which is up to 50 per cent of the vehicle cost of \$1,600 for a low-speed E2W, by making the battery manually removable and able to be separated from the body of the vehicle. They have offered an option that lets users lease the battery and subscribe to an arrangement in which a fully charged battery will be available on demand, at a chosen frequency depending on the subscription plan that they have selected.

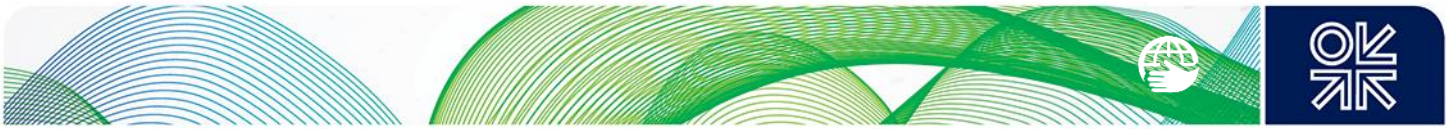
Figure 8: Illustration of how the depleted battery can be manually removed from an E2W or E3W and swapped for a fully charged one at a dedicated swap point



In the manual battery-swapping business model, the body of the vehicle is owned by the customer, but the battery is leased by the same customer ‘as a service’, against a monthly subscription payment which is much more affordable than paying the \$800 battery cost upfront. In a sense, this mimics the ICE vehicle cash flows, where the owner tops up the fuel in the tank at intervals. In the “full stack” EV with both the \$800 battery and the \$800 body, it is as if the owner is purchasing three years’ worth of fuel upfront. Most ICE vehicle owners could not afford such an upfront cost.

The monthly subscription payment for the separate, leased battery gives the delivery driver²⁸ access to a key fob (a remote keyless entry system via a built-in radio frequency ID system). This is used to unlock the battery cabinet at a designated swapping station (see photo on the right in Figure 8), into which the used battery will be deposited. The user also makes a small, fixed online payment of \$1–\$2 using a mobile phone each time a spent battery is deposited. This covers the electricity tariff cost incurred by the swapping station, for charging the battery that is being taken out. The user leaves the swapping

²⁸ So far commercial E2Ws make up only one per cent of all E2Ws sold (the Council on Energy, Environment and Water data confirms this for FY22). This market segment is expected to grow over time, but it is not yet the largest market segment. It is likely that most E2Ws are currently for personal use, while all E3Ws are for commercial use (either to transport passengers or goods).



station with a new fully charged battery. The whole process takes around two minutes and is much faster than the time taken to refuel an ICE vehicle with petrol or diesel. As a delivery driver going into various neighbourhoods throughout the day, the user can locate the nearest Energy Operator (EO, or owner of the swapping station) on a mobile app when needed. Unlike an ICE vehicle that can go to any petrol station, the EV battery swap can only currently take place within the designated EO's network of swapping stations. The app for now will therefore show only designated swapping stations, although state governments are working towards upgrading this to provide unhindered access to all swapping stations through battery standardization. This will soon extend the app's functionality beyond just showing certain swapping stations.²⁹

Under the battery-swapping business model, the battery is owned by a third-party, the EO. This may be a battery manufacturer who partners with the EV chassis manufacturer or may simply be a logistics company that buys the batteries in bulk from a different supplier who is the battery manufacturer. Either way, the EO's role is to sell a service that guarantees the convenient availability of a fully charged, leased battery whenever the customer needs to replace the battery because it is depleted.

The EO offers the E2W customers various payment options. The customers will choose the one that meets their needs, depending on how frequently the battery is swapped, and whether they also want a data package to monitor the battery's health, and state of charge, etc. (if so, the battery must have a SIM card).

What is the affordability issue and how does battery swapping allow adoption of more EVs?

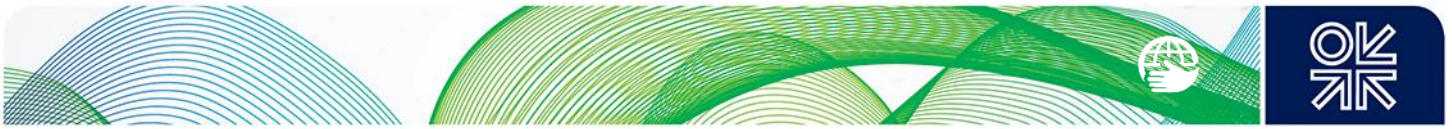
For some customers, their income is likely to be in the form of a daily income, for example, a full-time delivery driver working on a gig basis who is paid at the end of every day for the number of trips and hours worked. It is convenient for such customers to pay incrementally for the use of the battery, also daily or twice-daily, once the available battery range of say 50 km has been completed and the battery needs to be swapped because the daily driving distance may be longer.

After buying the vehicle for \$800 without the battery, a monthly subscription of around INR 1,600, or \$22, is paid for the battery-as-a-service. Note that after 36 such monthly subscription payments, the user would have paid \$800 in cumulative subscription fees, which is exactly the retail cost of a new replacement battery. However, the user is unable to pay the additional \$800 for the battery upfront. Also, the user does not want to own a battery that will cost another \$800 to replace when the warranty expires. Under the leasing model, the user has access to the battery but has no replacement cost to worry about. In this case, it is the EO who purchases the batteries, probably in bulk and at a discount, so the difference between the wholesale and retail cost of the battery is part of the EO's profit margin. If the customer wants a data package as well, the additional monthly cost is around INR 400 or \$5.

Therefore, there is a \$22 monthly subscription to qualify for the battery lease. Then there are the two daily battery swaps costing \$1 each, amounting to \$60 a month. There is also the \$5 data package to track and check the battery status on the mobile app ($22+60+5=87$).

Thus, the full cost of the battery-as-a-service for a heavy user such as a delivery driver comes to \$87 a month or just under \$3 a day. By Indian gig worker standards this is quite hefty since the daily income of some drivers during lean times, working 12 hours a day sometimes, is no more than \$6–\$7 a day (INR 500). A payment of \$87 for the battery costs represents 50 per cent of their daily income, which often amounts to no more than around \$180 a month (INR 14 000).

²⁹ If, in future, the government requires a certain segment of batteries to become 'standardized' and interoperable, then the number of suitable swapping points for removable batteries will become much larger, more like petrol stations, and swapping costs are likely to fall due to greater competition. It will also assist with the safe handling and recycling of end-of-life batteries, either for stationary applications or scrapping and recovering any reusable metals and minerals.



Therefore, even stripped down, there is still an affordability issue for EVs at the budget end of the mass market. This is why central government is currently determined to pursue interoperability as a way of accelerating the reduction in battery costs for E2Ws and E3Ws. They want to achieve this through large economies of scale, to localize the manufacturing of removable batteries of maybe 2–3 different ranges and capacities only. They then want to mandate that only this limited range of batteries may be used in all of the budget-category light vehicles that have removable batteries. They will go about this by setting standards for interoperability, which will increase the number of swapping stations that can be visited regardless of the make of the vehicle, and will increase competition in pricing the battery-as-a-service. It will improve safety and the ease of recycling end-of-life batteries.

This restriction/requirement for interoperability will clearly not apply to other EVs with fixed batteries at the higher and very top end of the 2W market, or to E4Ws. Manufacturers are free to offer as many proprietary technology³⁰ and patented battery management systems as they wish. The government is implying that variety is welcome when there is no affordability issue, but one or two basic models for budget EVs is what will help the lower-income segment in the entire country make the shift to e-mobility. For now, the government posted a draft Battery Swapping Policy³¹ on 20 April 2022 and seeks written comments from all stakeholders and the public as part of its consultative process for the new EV battery policy.

Results of a detailed research study on the total cost of ownership (TCO), comparing ICE 2Ws with EV battery-swapping and EV point-charging models

Dash, N. and Bandivadekar, A. (2021)³² evaluate if E2Ws in India with the battery-swapping option have achieved cost parity relative to E2Ws with the point-charging option and with conventional petrol 2Ws. The authors consider this by estimating the TCO of 2Ws in three use cases: personal use, ride-hailing, and last-mile delivery.

Figure 9: Selected use cases for the detailed study on TCO for three different types of drivers

Use case	Selected two-wheelers				
	BEV				ICE
	Okinawa iPraise +		Ather 450X		Honda Activa 6G
	Point charging	Battery swapping	Point charging	Battery swapping	Gasoline
Personal use	✓	✓	✓	N/A	✓
Ride-hailing	✓	✓	✓	N/A	✓
Last-mile delivery	✓	✓	✓	N/A	✓

Dash and Bandivadekar’s results show that for all three use cases, the E2Ws with point-charging and battery-swapping options are considerably cheaper than the petrol 2W. Additionally, while E2Ws with battery swapping are more costly than E2Ws with point charging for the personal and last-mile delivery use cases, the opposite is true in the case of ride-hailing operations, where the TCO of the EV with swapping is 15 per cent less than that of the same vehicle with point charging and 3 per cent less than a different vehicle that has no battery removal and works only with point charging. The fuelling cost is

³⁰ The government has mandated five specific charging standards and the proprietary technology will still be limited to these five charging standards.

³¹ https://www.niti.gov.in/sites/default/files/2022-04/20220420_Battery_Swapping_Policy_Draft.pdf

³² Dash, N. and Bandivadekar, A. (November 2021). Cost Comparison of battery swapping, point charging, and ICE two-wheelers in India. The International Council on Clean Transport. <https://theicct.org/publication/cost-comparison-of-battery-swapping-point-charging-and-ice-two-wheelers-in-india/>



the largest cost contributor across all types of uses for the battery-swapping option. If this cost is reduced, the battery-swapping model will become more cost-attractive because it has the unique advantages of zero opportunity cost (no driver waiting times) and zero battery replacement cost.³³

An alternative approach that is now being considered by e-commerce companies for deliveries

The boom in last-mile delivery and transportation needs for e-commerce deliveries has also been a key factor in driving electrification in the 3W segment of the transport sector, discussed below. Dalvi (2021)³⁴ is optimistic about growth in this segment and notes

In the face of high petrol and diesel prices and the accelerated need for speedy last-mile deliveries, the electric three-wheeler goods carrier segment has notched handsome 1,542% YoY growth to 2,644 units in H1 FY2022 from a low-base of just 161 units in H1 FY2021. This is also reflected in the growing share of EVs in the overall three-wheeler segment, which saw sales of 32,198 units: to 8.21% from just 0.62% a year ago.

In comparison, growth in the electric passenger carrier segment is more muted: 352% -- 4,757 units in H1 FY2022 from 1,052 units in H1 FY2021. Of the total 63,223 units sold in the overall three-wheeler passenger carrying segment, this marks more than doubling of market share: to 7.52% from 3.14% in H1 FY2021.

Given the affordability issues, it may be best if e-commerce companies in India just outright buy the EVs and pay for all transportation and operation costs related to deliveries. The drivers can be given a salary for their time driving around the company-owned fleet vehicles during the interim period while the Indian government tries to create the conditions to bring down battery costs. Once this happens, it may allow e-commerce companies to resume the driver-partner model where drivers bring their own vehicles, alongside the fleet, because market growth by that time will allow both models to coexist.

This is also the case in the US, where Amazon is investing in a fleet of 100 000 EVs and gradually considering moving away from the ICE driver-partner business model. This is still prevalent today, where individual owners of ICE vehicles use them to deliver the company's packages (see Figure 10 for Indian fleet EVs and Figure 11 for USA fleet EVs). In the US, each Rivian EV costs \$70 000. This is after Amazon has made a \$1 billion investment in Rivian and placed an order for 100 000 units. However, this arrangement is experiencing production delays and the full order will be delivered long after initial estimates.³⁵ In India, the EVs in the fleet each cost under \$5,000 or less than 7 per cent of the price of a Rivian, but they still deliver a good service despite such humble delivery methods.

³³ Detailed results are available in the paper and the interested reader is highly recommended to follow the detailed analysis and assumptions, which will be of great help to policymakers who are considering what to subsidize and how to bring down costs still further (<https://theicct.org/wp-content/uploads/2021/12/cost-compare-india-ice-2ws-ldvs-nov21.pdf>). Other very useful research studies that shed light on this market segment, and will inform policymakers, include two papers by the Alliance for an Energy Efficient Economy. Das, S., Sasidharan, C. and Ray, A. (September 2020). Charging India's Two- and Three-Wheeler Transport. <https://aeee.in/projects/charging-indias-two-and-three-wheeler-transport/> and Das, S. and Tyagi, B. (July 2020) EV-a new entrant to India's consumer basket. <https://aeee.in/projects/ev-a-new-entrant-to-indias-electricity-consumer-basket/>

³⁴ Dalvi, A. (November 2021). <https://www.autocarpro.in/analysis-sales/mahindra-treo-takes-45-of-electric-3w-market-in-h1-fy2022--piaggio-no-1-goods-carrier-80396> (accessed on 7 May 2022) .

³⁵ <https://www.aboutamazon.com/news/transportation/amazons-custom-electric-delivery-vehicles-are-starting-to-hit-the-road>
The article notes that Amazon has ordered 100 000 vehicles but there are production delays and far fewer have been delivered.

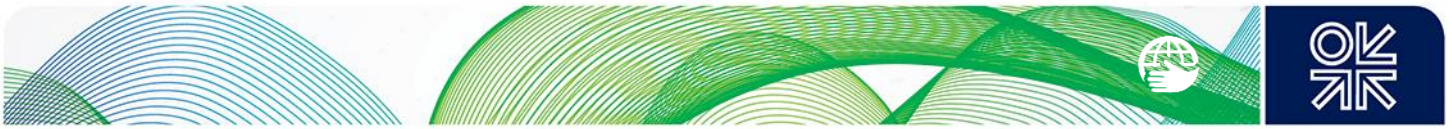


Figure 10: Fleet EVs of various kinds owned or leased by e-commerce companies



Figure 11: Rivian EV fleets for Amazon deliveries in the US



Something like the Amazon’s Rivian order is also taking place in India, but in the public sector, and according to the following business model: bulk orders are being placed to achieve an overall cost reduction through very large purchases. These large orders result from demand aggregation by a government entity called Energy Efficiency Services Ltd (EESL). EESL is the procurement and implementation agency of the central Ministry of Power.

In a bid to increase the percentage of electrification in the government’s vehicle fleet, EESL has been placing very large orders for 3W and 4W vehicles on behalf of some central and state government departments. The electric 3Ws (for messenger and package deliveries) and 4Ws (chauffeur-driven vehicles for officials employed by government departments) under government procurement orders are all manufactured domestically. Such upfront bulk orders are intended to enable established ICE vehicle manufacturers also to scale up their EV production facilities, based on guaranteed sales to EESL. This is believed to result in across-the-board cost reductions that will eventually benefit all consumers, including private retail consumers whose vehicles are not part of EESL’s order.



4. The EO's battery-swapping station charging service, versus the EV-charging network operator's charging point service³⁶

There is a subtle but extremely important difference between the EO swapping station charging service, involving leased batteries, and the public charging point service of an EV-charging network operator, involving wired charging. It helps the Indian EV market observer to understand why the EO battery-swapping station services are developing much faster than the wired/plug in EV-charging network. A manual battery-swapping station is a locally adapted, just-in-time market-driven solution for the mass-market budget segment, while the EV public charging network will gradually catch up with market demand and will mainly serve the E4W segment's range anxiety.

The flexibility of the EO's battery-swapping station charging service

An EO with, for example, battery-swapping stations in 20 locations, may only be able to charge batteries in some of the stations that it owns. This could be because the electricity distribution network is overloaded elsewhere or, more likely, that the stressed, state-owned local electric utility is unable to provide, for example, a 50 or 100 kW upgraded connection quickly for on-site battery charging in all 20 locations. But the EO is flexible and will therefore selectively charge the spent batteries wherever it can do so within its own locations, provided there is an adequate electricity connection available. The EO will then aggregate and transport the pile of spent batteries to a separate, designated location where the operator is able to obtain a suitable, heavy-duty connection from the distribution utility.

The difference between this business model and the business model of the wired/plug in EV-charging network operator is that the latter requires 'good sites' and a much larger footprint, with enough parking spaces. The site must be located in a highly frequented, desirable area, where people will come and pay for on-site charging. While the central government is issuing guidance to state and local governments to make public land available at a nominal cost for EV charging, not all public land may fit the bill, it may be a complicated procedure to secure the arrangement, or the land may not be in a commercially attractive location.

Finding suitable private sites at market rates is likewise proving to be difficult because the EV-charging network owner must first lease or buy the land for the charging station (such open, private land in an attractive location is very expensive and almost unavailable in congested urban areas in India). Market feedback indicates that the distribution utility frequently states that the nearby distribution transformers in such desirable locations are at full capacity, or overloaded.³⁷ This transformer overloading could often be due to existing, high levels of commercial activity in the area that is being considered for the public EV-charging point.

According to the electricity distribution company, booming businesses in the commercial area are already straining the distribution network. Most often this overloading has occurred as a result of commercial establishments gradually adding new, incremental loads, such as more air conditioners,

³⁶ The government has provided ample, high-quality guidance for private investors wishing to set up an EV-charging business under various business models. These include chargers for self-use; community use, for example, in offices; and public commercial use. There is a wealth of information in Niti Aayog's Handbook of Electric Vehicle Charging Infrastructure Implementation. (<https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pdf>).

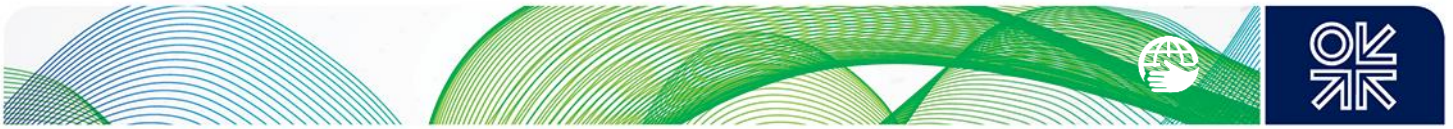
There is also consumer outreach in the form of Frequently Asked Questions and detailed answers to educate the public from the Bureau of Energy Efficiency. (<https://beeindia.gov.in/content/e-mobility>)

For additional implementation guidance, there is updated regulatory clarification along with samples of model contract documents from the Ministry of Power

(<https://beeindia.gov.in/sites/default/files/Final%20ConsolidatedElectric%20Vehicle%20Charging%20InfrastructureGuidelines%20and....pdf>)

The government has even arranged for a revenue-sharing model in which the EV-charging investor has a ten-year contract to rent public land at a nominal rate of one rupee per kWh of charging capacity.

³⁷ <https://www.thebetterindia.com/280479/india-electric-vehicle-revolution-ev-charging-infrastructure-network-experts-future/> (see section called Evolution of EV Charging Infrastructure)



refrigerators, dishwashers, and elevators. Given the limitations of network capacity and the local distribution transformer, the utility is unable to provide a new, large and heavy-duty connection on demand to the potential EV public charging point investor. The proposed solution would be that the EV-charging network investor also has to pay for a new, dedicated transformer as part of their EV-charging station business, along with the associated land for it. This causes costs to become unviable, or at least not recoverable through EV-charging revenues.

Also, the number of EVs on Indian roads is still very low, so there would not be too many visitors in a day. Therefore, the EV-charging price that would enable the costs of the fixed assets to be recovered within a reasonable payback period, would be too high for most EV owners. These are the major reasons why there are only a few thousand (under 2,000 by some counts) fixed public EV-charging points in the country today, against a projected need of 400 000 EV-charging points by 2025 and 2 million by 2030. There are around 50 Charging Point Operators (CPOs), indicating that the early stage of the wired charging market is still extremely fragmented and unorganized.

Some states are doing better than others in terms of facilitating their public EV-charging networks, but most of the operational charging points in India today are concentrated in only about nine cities across the country. It is almost as if the EV public charging network has not really come into existence yet, all government efforts³⁸ and subsidies notwithstanding.³⁹

In summary, the EO battery-swapping station business model for light EVs is much more flexible than the wired, public EV-charging network business model's requirements. The EO potentially has the option of collaborating with the distribution utility and to be guided in terms of being told (i) where the utility's last-mile electricity network is relatively under-loaded within a given urban area, and (ii) where they have available transformer capacity and can thus upgrade an existing connection to a higher contracted load, or else (iii) they can offer a brand-new heavy-duty connection of, for example, 100 kW or higher. The EO can therefore let the utility specify the closest nearby location for charging the stack of leased batteries.

The EO also does not require any parking spaces at the location where the heavy-duty charging rack is placed. The rack can be inside a shed or a room, or even at the back of someone else's factory where, for example, the full contracted load originally approved by the electric utility for the factory is not being completely used. This location, as directed by the utility, is where the EO takes the spent batteries, hooks up to a new or pre-existing, underutilized electricity connection, and charges the swappable batteries for about three to five hours before delivering them back to each of their respective swapping points so that subscribing customers will have access on demand.

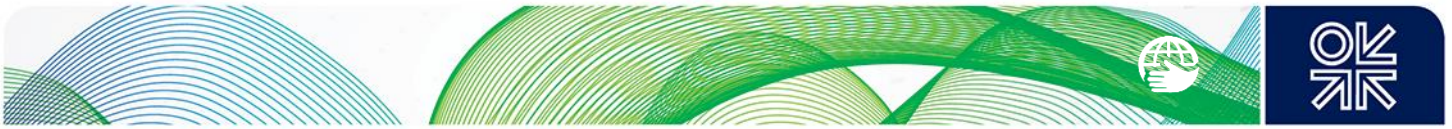
The EO is therefore neatly able to fill the flexibility gap in the market—they are not fussy about where the batteries are charged so long as they can be returned to the swapping stations before subscribers come for them. The best hope for the wired, public EV-charging network investor would seem to be in smart cities that are yet to be built, or along highways in less crowded parts in the outskirts of existing cities, where commercial and residential expansion is currently taking place. It is possible that land prices in such locations are not yet at a premium, and also that the distribution transformers are not yet overloaded.

A very segmented E2W market giving rise to multiple charging solutions

What complicates matters is that the market remains highly segmented. There is a different segment of somewhat higher income buyers of E2Ws for personal use, who are not delivery drivers or ride-hailing drivers, but instead could, for example, be an office worker or teacher. The daily distance travelled for personal use, or commuting, is estimated to be a small fraction of that covered by the other

³⁸ https://powermin.gov.in/sites/default/files/uploads/Revised_MoP_Guidelines_01_10_2019.pdf

³⁹ The 4W EV story (passenger cars) is not the subject of this paper, but it is worth mentioning that most owners of 4W EVs are well off and have their own parking spaces at home with reliable electricity connections and they are therefore able to charge their vehicles at home. However, they are still a tiny fraction of a percentage of the EV market.



two groups. In this case, the customer is usually willing to buy the full vehicle upfront, including taking ownership of the battery from the start. In this group, the customer does not want to pay the subscription and wants to keep the EV's original battery, which is not shared and possibly being mishandled by many users. The owner in this example also may not have access to a secure and dedicated parking spot with an outdoor electrical connection. Therefore, the owner needs to take the battery out of the vehicle and into the house for overnight charging indoors. For this group, the battery needs to be removable but not swappable.

Market feedback indicates that members of this group expect to replace the battery only after 4–5 years; they are anticipating a battery life of at least one extra year after the manufacturer's warranty (1,000 cycles) expires, because they will be able to take good care of the battery and follow all the manufacturer's instructions. They may also aspire to a better category of vehicle after 4–5 years. However, they know that, when that time comes, if their financial circumstances do not allow for a vehicle upgrade, then they will still be able to invest in a new battery for their existing vehicle (at a cost of \$800). This is an important lesson from the nascent EV market: while the battery replacement prospect may not be acceptable for delivery and ride-hailing drivers, it has strong appeal to this category of drivers using their vehicle for personal use. They will not share the battery with anyone else, but they need it to be removable from the vehicle so that they can take it inside for home charging, as needed.

A different segment of customers, probably in the higher-end 2W market, looking for premium E2Ws, has access to a secure parking garage at home with a heavy-duty charger next to the parked vehicle. They will use a cable and plug to charge the EV overnight on their premises. A fully charged, higher-end battery will give the driver a range of at least 100–125 km and may only need to be charged once every few days if they drive a maximum of 25–40 km a day. Such drivers do not want their battery to be removable. In fact, for this market segment, the manufacturers have designed an anti-theft feature that locks the wheels and even alerts the owner through their mobile app if anyone is tampering with the battery while the vehicle is parked.

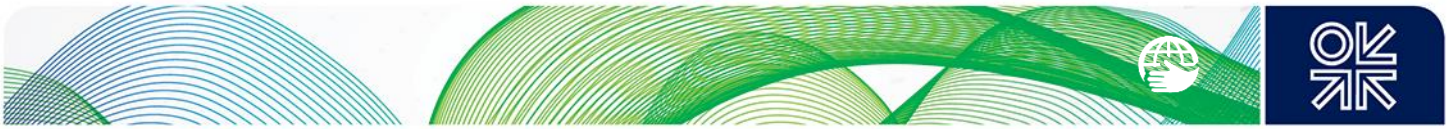
Each one of these solutions is in some ways a response to unique and unanticipated challenges such as delays in constructing the public EV-charging network. There is also the pressure faced by workers in the gig economy that does not enable a delivery driver to spend three hours waiting for a light commercial vehicle to be charged at any charging network, whether it is a public EV-charging point, or a dedicated in-house one at the e-commerce warehouse. Slow or even fast charging does not work as the worker will thereby lose a quarter of their daily income in a twelve-hour day. Others, with different charging possibilities and different opportunity costs, have different EV preferences, based on their personal circumstances. In future, when the public EV-charging network has caught up with demand, they will probably have less range anxiety and will increase the use of their personal EVs, thereby increasing the clean kilometres travelled.

5. The way forward

Today, around 99 per cent of vehicles running on India's roads are powered by internal combustion engines running on fossil fuels (petrol, diesel, and some CNG). The passenger car is still a largely aspirational product for around one hundred million newly middle-class Indians (20 million families). Fortunately, given the current, still very low per capita car ownership in India of 22 per 1,000 citizens, compared to 980 in the US and 850 in the UK,⁴⁰ it is an opportune time for India to embrace alternative sustainable mobility solutions for a green and prosperous future. In other words, there is still a short window in the coming decade up to 2032 for the government to incentivize clean transportation in an inclusive way, and at scale.

This can only succeed if accessible and affordable solutions are available in adequate numbers. Also, given the segmented nature of the market and the different dynamics within each segment, government

⁴⁰ <https://indianexpress.com/article/technology/opinion-technology/how-shared-electric-mobility-can-benefit-india-5593408/>



support could be better targeted. This effort has already started with the proposed interoperable and standardized light-vehicle battery, to promote greater affordability in the battery-swapping segment. Also, government incentives for increased localization of battery assembly, and eventually cell manufacturing, as well as continued public support for R&D to explore alternative battery chemistries, will all help to reduce costs.

The real challenge for India lies in E2Ws and E3Ws, used by nearly 1 billion people in the country every day. Converting these vehicles to electric, making them affordable and convenient, and doing what it takes to turn E2Ws and E3Ws into the first preference over ICE vehicles when making a purchase decision, is what India should be supported and measured on.

In India, the adoption of e-mobility through the individual purchase of EVs is not likely to happen very fast in the mass segment of the market, (180 million families or 900 million people) even for 2Ws with leased batteries, selling at a price point today of under \$1,000. It is likely to require a few more years until battery prices come down to around half of what they are today. The important lesson for EV market players in India is that the cash flow patterns of the mass market segment, such as for example a delivery driver's daily or monthly income, do not allow the owner to pay the \$800 battery cost upfront in addition to buying the body of the EV for another \$800. Even the battery leasing option, amounting to an estimated \$87 per month for a gig worker, is a financial stretch. This is extremely important in a low-income consumer market where high-cost products such as lithium-ion EV batteries are supposed to be adopted by consumers who are struggling financially. Despite the billions that the government has set aside to lower the upfront cost of entry, it appears that the product may still be out of reach for most of the budget market, until the battery costs and battery leasing costs fall further. India's ongoing attempts to standardize a subset of swappable batteries for the light-vehicle segment, to make them interoperable across multiple vehicle brands, are likely to increase affordability and create market confidence, as one type of battery becomes 'commoditized'. Additional government efforts to localize the manufacture of batteries and cells, and the use of public resources to fund R&D on alternative battery technologies, will all help in the quest to lower battery costs and speed up the adoption of e-mobility at all income levels of society.