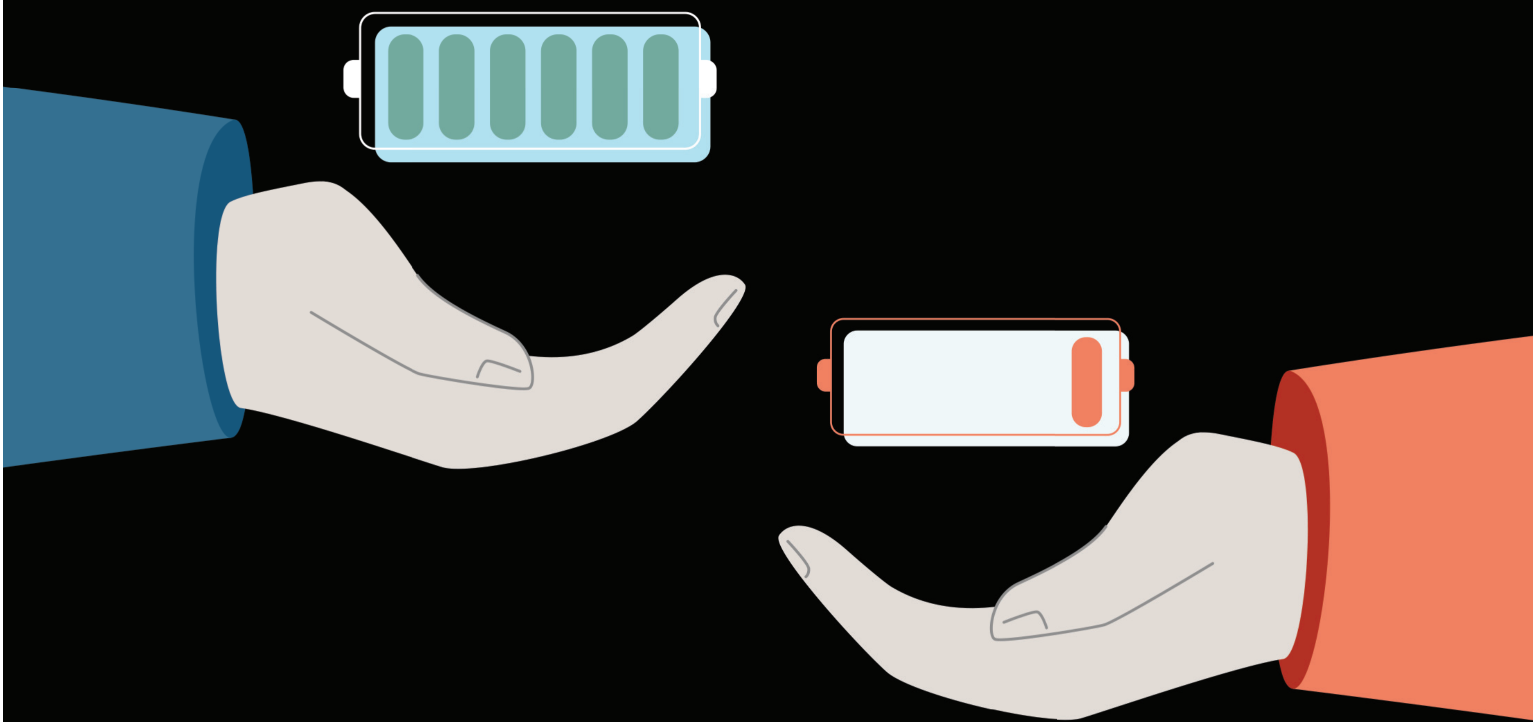
BATTERY SWAPPING FOR UPSCALING VEHICLE FLEET ELECTRIFICATION

A PRIMER



BATTERY SWAPPING FOR UPSCALING VEHICLE FLEET ELECTRIFICATION

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1. The spotlight

As India is building its ambition for electrification of the new vehicle fleet and developing strategies for scalability, policy interest in battery swapping is gaining ground. In the Battery as a Service (BaaS) business model, it is possible to delink the battery, and the battery is offered through a system of lease or subscription.

An electric vehicle (EV) user can easily and quickly replace a discharged battery with a fully charged one at any designated swap station—and it is faster than filling a fuel tank. The EV users can pay a regular subscription fee for batteries to the service providers throughout the lifetime of the vehicle.

This strategy has drawn considerable attention in India and in other developing countries to leverage this as an enabler to fast pace fleet electrification at the early stages of the programme. In the price-sensitive markets of the developing economy, this subscription model helps to lower the upfront costs of EVs significantly as batteries—that form up to 40 per cent of the total cost of the EV—can be delinked from the final price of the vehicle. This drastically reduces the upfront cost and cost of ownership, making EVs affordable. This is also attractive in markets with limited public charging network.

These countries have not only adopted battery swapping as a BaaS subscription model targeting two-wheelers and paratransit vehicles, but they have also implemented Mobility as a Service (MaaS) that offers a complete mobility solution, including battery swapping. These service providers are not only aggregating the batteries for swapping but also providing vehicles for taxi service and deliveries.

This business model is primarily driven by start-ups and to a great extent, it is self-propelled. The business has taken off even before policy, regulations and standards have taken shape across geographies. However, the regulatory, technical and financial framework for this programme will require a closer attention in order to ensure safe operations and to build sales and performance.

Benefits of battery swapping: Battery swapping offers a fast, convenient method to recharge electric vehicles (EVs), reducing downtime and making EVs more readily available as compared to traditional charging. With adequate battery swapping infrastructure, the requirement for specific vehicle segments that use swappable batteries can offset demand for point charging infrastructure in the commercial segment.

While battery swapping requires a higher volume of batteries, each unit can have a lower capacity (kWh), as range anxiety is reduced. This will require adequate network density of swapping stations.

Swapping can encourage the use of smaller size batteries and further help to reduce costs and improve energy efficiency. Wherever large batteries are needed for heavy-duty vehicles (HDVs), they may be dispensed through automated modularized swapping stations.

Battery swapping offers benefits of preserving battery health as it leverages the slow charging advantage at the stations. As a result, swapped batteries last longer and cost less to use.

Swapping stations can leverage the advantage of slow charging with lower priced electricity at night. Additionally, using smart meters can bring further value by leveraging vehicle to grid opportunities.[1]

This allows future upgrades to higher-capacity batteries, potentially extending the overall service life of EVs.

Swapping stations also enable frequent battery inspections to monitor performance and lifespan to preserve battery health, plan its second use and eventually, recycling. The stations can be designed to offer a significantly faster rate of "recharging," thus, reducing overall wait time.

It is also possible to link swapping stations with on-site solar power generation to reduce dependence on the grid. These can integrate solar power for standalone electricity storage. Swapping stations and swappable batteries can considerably save cost of up to 40 per cent with a local renewable energy supply to power the batteries.[2]

Standardized battery dimensions and specifications would also help manufacturers achieve economies of scale.

Unlike point charging stations, which need parking space for vehicles during charging, battery swapping stations can store multiple batteries vertically, addressing space constraints in urban areas.

Given these advantages, there is an immediate need for battery swapping strategy to focus on regulatory, institutional and financial support for its scalability. This strategy has a particular appeal for commercial fleet operators who need to maximize their operational hours to improve earnings. Swapping helps them reduce long downtime that is usually associated with point charging. This is evident in the price-sensitive market of small format vehicles, such as two- and three-wheelers and paratransit vehicles that are being inducted for deliveries, taxi operations and last mile connectivity. These segments also dominate the on-road fleet in Indian cities.

Policy imperatives of battery swapping: The policy discussion on battery swapping business is increasingly moving towards standardization, harmonization, and interoperability for seamless operations. As the number of service providers are increasing, it is fragmenting markets and clientele as the systems are currently not interoperable. This means a battery designed by one EV brand can be safely and efficiently swapped into another EV of a different brand. This requires common standards for battery form factor, connectors, and a communication protocol. This can create more open systems for clients to access batteries and swapping stations seamlessly and reduce cost effectively. Achieving compatibility and interoperability among various manufacturers is essential for widespread adoption and to build scale.

While this may sound like the most logical approach to take, it has turned out to be the most contentious issue among service providers and manufacturers. Many fear that at the early stages of industry growth, standardization can undermine competitive advantage of the industry and stymie innovation. Even though this is perceived as one of the most pressing needs in the sector, even globally, the comprehensive rules and standards for interoperability are yet to be implemented.

Therefore, the focus remains confined to meeting the safety requirements and related standards for batteries and EVs. However, there are still gaps in the regulatory approach and implementation strategies that need to be well understood and addressed.

Current challenges related to battery swapping: The regulatory framework for battery swapping stations must be tightened to address the performance parameters, tax structure, operational ecosystem, interoperability and standardization of EV batteries. This is to ensure that different battery types and swapping systems can work together, enable data sharing and communication, apart from a common electricity access and tariff, recycling strategy for swapped batteries and to define the scope of swapping application in all vehicle segments.

The Draft Battery Swapping Policy 2022, as developed by NITI Aayog, was followed by a set of standards established by the Bureau of Indian Standards (BIS) for safety and testing in order to enable safe and cost-effective infrastructure for swapping of EV batteries. The Ministry of Power had, in January 2025, issued guidelines governing installation and operations of battery swapping infrastructure. Battery swapping requires careful handling of large amounts of portable electrical energy, necessitating rigorous safety protocols. Improper handling or maintenance can increase risks.

Currently, the national regulations and policies are primarily designed to address the fixed charging stations and incentives are linked with the size of the batteries and are disbursed per kilowatt-hour (kWh) of battery. But vehicles designed with battery cavities are sold without batteries. Financial instruments and long-term financing schemes are not easily available currently to meet the high capital costs of swapping stations. Setting up battery swapping stations involves substantial investment in land, equipment, and skilled personnel. Access to capital for setting up swapping stations needs to be addressed.

Financing the battery swapping ecosystem requires policy attention. There are expectations that the governments will intervene with Viability Gap Funding to meet the needs of this high capital expenditure (capex) business. Some of the state-level EV policies have included battery swapping stations for both financial and non-financial benefits.

Several other issues also must be addressed. Swapping regulations need to cover all four-wheeler vehicle segments as currently these are confined to only two- and three-wheelers. Even though registration of EVs without batteries are now allowed, there are still glitches as often official software is not updated to enable the registration of different kinds of EVs, including separate battery registration. More attention needs to be paid to the standardization of batteries, operational safety and end-of-life management.

The *Guidelines for Installation and Operation of Battery Swapping and Charging Stations* issued by the Ministry of Power on 19 January 2025 permits owners of swapping stations to use an existing electricity connection with or without seeking an increase in the connected load, in order to charge the swappable batteries. If the electricity demand increases, they may be required to obtain a high-tension connection and set up a transformer to cater to relevant voltage of swap stations. This also requires attention to quality of power.

The next steps

Battery swapping strategy is an opportunity for upscaling electrification especially in the developing markets that are more price sensitive and where upfront capital costs can be a barrier to building rapid scale. This market has begun to progress even before the regulations could be fully developed. However, the market needs to be governed by well thought out policies and regulations to maximize productivity, safety and performance. This requires some priority measures:

1. **Need comprehensive battery swapping policy** to define the scope of application across vehicle segments; requisite safety, performance and interoperability standards; cohesive and harmonized set of regulations for battery swapping stations, and their requisite audits.

2. **Strengthen safety parameters** for battery swap stations.

3. **Address issues related to homologation and registration of vehicles** without batteries and batteries at the point of registration.

4. **Develop phased approach to interoperability and standardization** and define the technical and communication protocol accordingly to address multiple applications and operative approaches. Additionally, address issues related to innovation, safety and liability.

5. **Develop fiscal incentives and financial instruments** to support the high capital investments similar to the ones provided for fixed charging stations. Rationalize GST and other taxes to reduce costs.

6. **Align requirement of battery swapping industry with battery R&D roadmap** on future battery chemistry, battery efficiency, etc apart from skill development.

7. **Promote integration of battery storage** in swapping stations with the grid and grid services. Regulate bidirectional energy flow to support grid stability and renewable energy integration.

The Indian Battery Swapping programme has the potential to create a strategic learning curve for other developing countries especially in Africa and Asia where battery swapping has taken off already. Several companies have emerged to provide Battery-as-a-Service (BaaS).

As this is a new area of intervention and a vastly different approach from fuelling of internal combustion engines, there are often a range of curious questions raised by EV users and policy makers. Therefore, this policy brief is designed to address those frequently asked questions to deepen understanding of this strategy and the way forward.

2. How does battery swapping work?

Battery swapping technology fundamentally differs from point charging by centralizing battery management. The stations are equipped with system for exchanging used batteries with fully charged ones. Broadly, these include a swapping system, a control system, and a power supply system. The level of automation and manual operations vary depending on the nature of the stations.

In a battery swap station, batteries connect to a central management system. The control systems manage charging, swapping, and station operations, while power supply system ensures reliable energy for charging and station functions. It also tracks status and usage. Batteries are stored in modules that typically hold 15–20 units, and a swapping system has three main components: the electric vehicle, the battery pack and the battery swapping station.

Battery swapping for EVs requires comprehensive planning to ensure availability of batteries, chargers, and secured data management through cloud services, seamless communication and interoperability across system components.

The Battery Swapping System (BSS) relies on consistent communication between the vehicles, swapping stations and an integrated information system to function effectively. The information system connects the vehicle with the swapping station. When a vehicle's battery level is low, it communicates with the system to request a battery swap. The system then relays the vehicle's location, estimated arrival time, and identification details to the nearest station, preparing the necessary battery in advance.

The driver swipes a membership card, allowing the information system to retrieve data associated with the account, including vehicle details, battery information, swapping history, and transaction records. Station staff verify this information and guide the customer to the swapping area, where the battery exchange occurs. All data is securely backed up, ensuring transparency throughout the process.

After the swap, the new battery is monitored for key metrics such as state of charge (SOC), state of health (SOH), remaining capacity, age, and cycle count. The vehicle owner is notified of any charges and the estimated time to receive a fully-

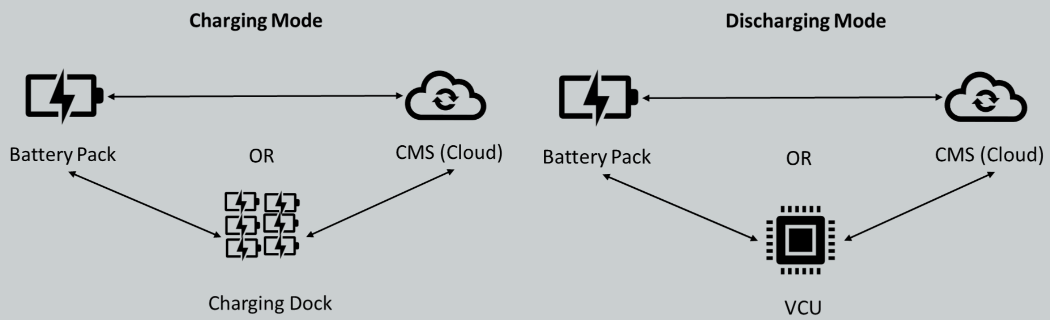
COMPONENTS OF BATTERY SWAPPING STATIONS

Battery pack: The battery pack comprises one or more cells configured in series or parallel to form a complete power solution, with integrated safety and management systems. Each cell contains an anode (negative terminal), cathode (positive terminal), and a separator to prevent short circuits. For conventional lithium-based batteries like NMC (nickel manganese cobalt) and LFP (lithium iron phosphate), a liquid electrolyte enables charge transfer between the anode and cathode. Metal current collectors at each end of the cell allow efficient current flow with minimal loss.

Charging dock: This dock charges and stores batteries, with each slot equipped with connectors that interact with the battery's BMS. The dock's enclosures, typically made from insulating plastics, protect against short circuits, electrolyte leakage, and user electrocution. These materials are also resistant to alkaline reactions, thus, ensuring safe operations.

Charger connectors: Connectors link the battery to the charging module (for charging) or to vehicle propulsion system (for discharging). These connectors, similar to the ones found in household devices, regulate electricity flow and are enabled by switches. Battery-swapping systems require two types of connectors—one fitted to the battery and another to the charging or discharging device.

Central Management System (CMS): The CMS is the core software managed by the BaaS operator, comprising an Operator Platform (BOP) and a User App (UAP). The battery communicates with the CMS either directly (via telecom or Wi-Fi) or indirectly through the vehicle control unit (VCU). When the battery is in the charging module, it communicates through Controller Area Network (CAN) protocols, telecom, or LAN/Wi-Fi connections. Since swap docks lack the necessary data-handling capacity, the CMS is typically cloud-hosted.



The different swapping techniques are based on the position of the battery in the vehicle and the point of application of the robotic arm.

1. **Sideways swapping**: when the battery is lodged sideways and its manual replacement is most convenient.

2. **Rear swapping**: when the battery may be fitted at the back of the car.

3. **Bottom swapping**: when battery is placed at the bottom of the vehicle. The car is placed on an elevated platform and the batteries are swapped from the bottom using a robotic arm and other accessories.

4. **Top swapping**: when the batteries are placed at the top of the bus. The rooftop opens up and the swapping is completed by means of a robotic arm. This technique is likely to complete with a pantograph charger.[3]

charged battery. Batteries are then placed in charging racks, where the Battery Management System (BMS) oversees safety, voltage, and cell temperature. Some vehicles may also require a reset of the charging system monitoring after battery replacement.

The high-voltage battery connector is manually attached to the vehicle and charging begins only when a secure connection is established. That is ensured by a safety latch that allows current flow only when properly sealed. Additionally, the swapping station supports bidirectional power flow with the grid, potentially enhancing grid efficiency by charging during off-peak hours and supplying power back during peak demand. This scheduling approach enables stations to generate revenue by selling power at high demand and borrowing when demand is low.

The main components of a station include distribution transformers, AC-DC converters, battery chargers, vehicle batteries, charging racks, maintenance systems, and control systems. The station can be configured with either a centralized AC-DC converter connected to a distribution transformer that supplies DC power to all chargers or individual AC-DC converters at each charger. The latter setup is typically preferred as it allows continued operation even if one converter fails, whereas a centralized converter would be larger, costlier, and more challenging to install.

The control room of the battery swapping station manages the system's operations. Charging racks support both slow and fast charging for electric vehicle supply equipment (EVSE) while battery racks accommodate this process. The swapping track enables logistics, safety checks, and both manual and automatic battery swaps.

3. Application of battery swapping in different vehicle segments

While swapping is technically possible across all vehicle segments—two- and three-wheelers, cars, buses and heavy-duty trucks and buses—the swapping market is currently limited to two- and three-wheelers in India. There have been some pilots on battery swapping in the bigger vehicles but these are not at commercial scale yet. Increased costs, technical complexity related in handling bigger batteries, and the need for advanced automation have stymied this change.

In the advanced markets of US and Europe, swappable batteries have been introduced in cars. In China, along with two-wheelers, cars, buses and trucks have also been brought within the scope of the programme.

Two- and three-wheelers: Currently in India, battery swapping system has evolved more viably for the small format vehicles like two- and three-wheelers. Their low battery weight and swapping infrastructure cost are an early enablers. Indian companies have set up modular, manual battery swapping stations for lightweight electric vehicles. These compact battery swapping modules contain 15-20 batteries per module. Batteries for two- and three-wheelers are lightweight and easy to swap manually. There is yet another model in which they do not have modular docks. Instead, they store and charge their batteries in insulated racks.

Passenger cars: This is yet to take off in India. In the US, Tesla had patented a robotic battery swapping technology for its Model S and Model X electric cars in 2017. It claimed that the robot can lift a car and change its battery pack for a new one within 15 minutes. The robot could also be mounted on a trailer and the vehicle could be driven on and off it. Tesla's patented robotic battery swapping technology could reduce downtime but is still not widely adopted. Overall, the car industry is more oriented towards pre-fitted batteries and not in favour of swappable batteries.

Heavy-duty vehicles: Battery swapping for medium- and heavy-duty vehicles, including electric buses, is technically possible. However, the cost of setting up battery swap systems for four-wheelers and bigger commercial vehicles can be significantly high and technically complex. The battery packs used in such vehicles are much heavier and requires robotics at an automated swapping station in order to make the switch. It requires special equipment and supportive infrastructure. Although capital intensive, it has been done before in India. In 2019, Ashok Leyland, in collaboration with Sun Mobility, had carried out a battery swapping pilot for 18 electric buses in Ahmedabad.

In China, battery swapping for heavy-duty trucks has taken off. In 2021, there were 13 models, out of which 11 models provided both battery-swapping and cable-charging solutions for energy supplements. About 400 such trucks were in operation. The dominant battery size is 282 kWh and uses lithium ion cells. The size might vary between 50–500 kWh.[4] Chinese companies have innovated the modular design of the trucks to enable swapping. As per a study by the International Council on Clean Transportation (ICCT), the share of swap-capable vehicles in China's electric truck sales has been increasing. In 2022, a total of 49.5 per cent of the electric trucks sold in China were swap-capable.[5] In China, there were about 3,924 battery-swapping BEV (Battery Electric Vehicles) accessed to the National Monitoring and Management Platform by the end of 2022, including 3,431 BEV heavy-duty trucks.

4. What is the structure and scale of battery swapping industry in India?

According to the India Battery Swapping Association (IBSA), there are over 3,500 battery swapping stations in India, with over 350,000 batteries in circulation, facilitating electric trips of over 7 million km daily. As per available information, IBSA represents firms with over 95 per cent of the swappable batteries in operation.[6]

India's EV battery-swapping industry is growing rapidly, valued at approximately USD 10.2 million in 2022 and expected to reach USD 61.57 million by 2030 with a compound annual growth rate (CAGR) of 25.2 per cent.[7] The growth is fuelled by the move towards cost parity between EVs and ICE vehicles, along with reduced charging times. As noted earlier, adoption is mainly driven by electric rickshaws and three-wheelers (3Ws) as they have light-weight batteries which are easier to swap manually. The 3W segment led the market in 2022, holding about 90 per cent of revenue share, while the two-wheeler segment is expected to witness CAGR of 32 per cent between 2022 and 2030.

Several companies—national and global—have emerged over time, even though only a few dominate the market. Most of these players are start-up companies and operate in metropolitan cities such as Hyderabad, Bengaluru, Delhi and Mumbai. More than 20 such companies operate today in different markets. Some of the prominent start-ups include Sun Mobility, BatterySmart, Ola Electric, Lithion Power, Voltup, Race Energy, ChargeUp, Esmito, Numocity, Okaya Power group, Gogoro, Battery Pool, Yulu, Amar Raja Power System, Mechlae Energy, Evoride Motors Pvt Ltd, SMV Green Solutions Pvt Ltd, NXTmile Mobility, GridXenergy, Alphatron Electric Mobility Pvt Ltd, among others. Some of them are global players.

5. What is the typical business model of a battery swapping company?

As noted earlier in this report, there are two broad business models—battery as a service (BaaS) and mobility as a service (MaaS).

BaaS earns from subscription or pay, peruse, charge arrangements for battery charging, maintenance and swapping services. This primarily targets the Business-to-Consumer (B2C) segment which sells products or services directly to individual consumers without intermediaries like wholesalers or retailers. In this case, individual users or fleet operators maintain ownership or leasing of their respective vehicles or fleets. This reduces the capital expenditures for battery service operators as the vehicle's ownership remains with the user. However, this has limited reach for the Business-to-Business (B2B) sector where one company/organization sells goods and services to another business. For example, Battery Smart and Sun Mobility are providing this service.

Mobility as a Service (MaaS) offers a complete mobility solution, including battery swapping and generates revenue from subscription fees, usage based charges, or both. The battery is included in the vehicle, along with additional services such as insurance and maintenance. This is a comprehensive subscription-based solution for B2B clients to decrease the assets managed by business proprietors. This is an asset-light solution which helps increase the number of customers. But in this case, the players acquire ownership of the vehicle and is associated with high capex and inventory. This requires high vehicle utilization for return on investment. Companies such as Sun Mobility, Bounce Infinity and Zypp are providing this service.

Additionally, 'India EV Digest' released by the Ministry of Power has described some of the existing business models.[8]

In the partnership model, the OEM provides batteries and charger at subsidized rates to the operator/partner while the cost of land and operations is borne by the partner. Maintenance of battery and chargers is OEM's responsibility. This helps lower the capex and opex for the operator. For example, Battery Smart, a battery swapping provider, offers BaaS.

In the revenue sharing model, the battery swapping operator possesses and oversees the charger and batteries while also being responsible for its operation and maintenance. The land is supplied by a land-owning agency, and the OEM splits and shares the revenue with the land-owning agency. The revenue is determined by the earnings from battery swapping business. The capex and opex are borne by the battery swapping operator. For example, Sun Mobility has adopted this model.

Battery swapping companies aim to price their services on par with or slightly below the cost consumers would incur to purchase and charge their own batteries. For example, lead-acid battery users may spend Rs 200–250 daily on charging, while swapping providers offer similar costs per day but add benefits like larger uptime. Franchisee partners generally sign three-year contracts, pay an upfront fee, and recoup investments within a year. The battery swapping company pays the partner per transaction, covering electricity and rental costs, while maintaining a sustainable margin.

Currently, some companies handle 80,000 swaps per day, with each swap generating around Rs 60 net after taxes, discounts, and partner payments. Despite positive EBIT (earnings before interest and taxes), high depreciation and interest costs prevent companies from achieving positive EBITDA (earnings before interest, taxes, depreciation, and amortization). EBITDA is a method of evaluating a company's profitability by focusing on its core operating performance. This leads them to raise venture capital. Scaling up operations to three to four times their current size is necessary for these companies to reach profitability.

Table 1: Unit economics of a model battery swapping station

Typical total costs involved in operating a battery swapping station	
Partner's Investment	Rs 7,50,000
Breaking even in 10 months with a 49 per cent income by the 16th month	
Total costs (monthly basis)	Values in Rs
Revenue	1,57,500
Expenses	80,000
Monthly Income	78,000

Source: Battery Smart

The total cost of ownership for a consumer is expected to reduce with increasing daily utilization and enhanced scale with regard to battery swaps, customers, players and consumers. This will improve the unit economics of the battery swapping industry significantly. At the moment, it is severely impacted by the large capex required to set up swap stations.

The large capex is due to the large volume of batteries that the company has to stock and maintain in order to enable smooth operations. However, this can be addressed with larger numbers of automakers committing to manufacturing swap-enabled vehicles with standardized battery cavities and an expansion in the swapping network. This could enable scale and help reduce the cost of the service.

6. How do battery swapping providers plan their network?

Network planning is driven by data on customer behaviour such as the frequently-travelled routes and the amount of traffic passing by at any given time. Using this data, service providers decide where to open new swapping stations and determine their capacity. This data also helps redirect customers to nearby stations when their batteries are running low, optimizing the network's efficiency.

The network planning process must balance three key objectives:

Proximity: Ensure that customers can access a swapping station within a 10-km driving distance.

Wait time: Minimize wait times for customers. Ideally, there should be no waiting for a battery swap. If a station has 10 batteries but 30 customers arrive at once, some customers would have to wait. Providers aim to eliminate this scenario.

Maximizing battery utilization: Prevent the over-deployment of batteries which could lead to idle batteries sitting unused. On the other hand, insufficient batteries would mean a longer wait for customers.

7. How cost effective is swapping?

These objectives can conflict with each other. For instance, prioritizing customer proximity and minimizing wait times could result in excessive battery deployment. Conversely, focusing on maximizing battery utilization could compromise customer experience. To solve this complex problem, battery swapping providers rely on predictive algorithms that forecast with high accuracy when and where customers will need a battery swap. This allows them to dynamically adjust the network, adding new stations and adjusting capacity as needed.

This is a cost-effective model. A total cost of ownership (TCO) analysis by the ICCT revealed lowest values for both conventional two-wheelers and electric two-wheelers when the vehicles have high utilization rates in applications such as e-commerce deliveries and shared mobility. Notably, electric two-wheelers consistently proved to be more cost-effective than gasoline vehicles. Point charging remains the most affordable option at low- and medium-utilization rates (under 100 km per day), even with relatively high domestic electricity rates. However, for daily utilizations of over 140 km per day, battery swapping becomes the most economical choice. The ICCT has also found that if the cost of battery swapping were to reduce from Rs 34 per kilowatt hour (kWh) to Rs 20 per kWh, then battery swapping would be the most appealing option for daily utilization starting at 120 km.

Overall, industry estimates indicate that swapping offers a more cost-effective option across all vehicle segments including electric three-wheelers, buses and trucks as compared to fixed charging. The total cost of ownership (TCO) of a city bus in Ahmedabad, for instance, was found to be more cost effective.

8. What is the policy and regulatory framework for battery swapping in India?

The policy interest in battery swapping gained credence in the Union Budget of 2022–2023, when plans to introduce a Battery Swapping Policy and interoperability standards were announced with the intent of building and improving the efficiency of the battery swapping ecosystem.

In April 2022, NITI Aayog had released the first draft policy on battery swapping for EVs recognizing its importance in accelerating adoption of battery swapping technology and BaaS business models to achieve lower upfront costs, minimal downtime, and lower space requirements for charging. It also highlighted the technical, regulatory, institutional, and financing challenges in developing battery swapping ecosystems.

The policy aimed to promote swapping of batteries with Advanced Chemistry Cell (ACC) batteries, allow EV users to have flexibility of utilizing alternative to charging facilities, lay out the key principles for development of technical standards to enable the interoperability of components within a battery swapping ecosystem without compromising market-led innovation, developing an ecosystem of swapping services with compatible components (batteries, vehicles, chargers, etc.), promote battery recycling management to maximize battery usage, and provide policy and regulatory levers to de-risk the strategy and enable competitive financing. This is expected to unite a diverse group of stakeholders—the battery providers, battery manufacturers, original equipment manufacturers (OEMs) of vehicles and the financial institutions.

Therefore, the draft policy included technical and operational requirements including standardization for battery and swapping stations, Unique Identification Number (UIN) for batteries; testing and certification for battery swapping components; battery charging and swapping infrastructure; data sharing and communication; along with fiscal support, swapping as a service, recycling systems etc.

However, the main focus is on the framework for interoperability to be defined for charging and discharging process, compatibility of fixed or swappable batteries with different EV models—with the EV supply equipment (EVSE) provided in different systems. This is a critical aspect of regulations related to swapping. This enables seamless swapping of batteries across different EV models and brands; makes it easier for users to widely adopt battery swapping technology, and easily switch between service providers and EV models without the need for specific adapters. Standardization of battery designs and interfaces can minimize the need for each swapping station to stock multiple battery types that can reduce inventory costs and operational complexity. The competition can improve products and services. More cost effective and standardized infrastructure is possible.

Yet, this has turned out to be the most contentious part of the regulations. The swapping industry is deeply against such standardization at this stage of development as they fear loss of competitive advantage. A fixed form factor and a standardized design can limit and stymie innovation and advancement in swapping techniques. There could also be a problem with universal batteries as different vehicles have different software and hardware requirements, dimensions etc.

As of now, there is no comprehensive battery swapping policy. NITI Aayog had drafted the battery swapping policy in 2022. Additionally, the Ministry of Road Transport and Highways (MoRTH) had issued a circular in 2017 that provides registration of electric two- and three-wheelers without batteries, which is based on type approval by the accredited testing bodies. However, this does not include other categories of vehicles.

According to the industry observers, the certification system requires more clarity to enable registration. But the incentive policies of the Government of India—both demand incentive and production-linked incentives—do not support battery swapping, battery swapping stations or swappable vehicles. *The Charging Infrastructure for Electric Vehicles– Guidelines and Standards*, 2018 are also not explicit on battery swapping. Yet another concern remains that while fixed batteries pay 5 per cent GST, swappable batteries that are sold separately are taxed 18 per cent GST.

9. How can we strengthen the enablers?

Registration of vehicles without batteries: The MoRTH permitted the sale of e-two and three-wheelers without a battery pack. The MoRTH circular RT-11036/72/2017 regarding "Sale and Registration of Electric Vehicles without batteries", dated 12 August 2020, states that vehicles without batteries can be registered if type approved by the testing agencies. This can be done without specifying the make and model or the details of the battery. This notification only covers the two-and three-wheelers and not four-wheelers. This limits the scope of application. More interventions, guidance and software upgrades are needed to improve the registration process and include details with respect to removable and swappable technologies.

Homologation challenges: The current homologation rules do not account for multiple docking of the battery, thus leaving a challenge and loophole in terms of battery safety. A major safety issue arises with crash safety, as these batteries may be owned, maintained, and charged by one entity but used by multiple users.

Homologation of any vehicle registered under the Central Motor Vehicle Rules, 1989 has a provision for type approval (TA) for initial certification of the vehicle model followed by Conformity of Production (COP) testing to ensure that the vehicle model is being accurately represented in the assembly line production. This rule is being interpreted by the regulators as a combination of TA and COP tests for vehicles without the battery combined with separate testing of the battery.

As per the MoRTH circular RT-11036/72/2017, vehicles without batteries can be registered based on the TA certificate without the need to specify the make/type or any other specifications of the battery. Any vehicle with a swappable battery should be registered without reference to the battery details to ensure the validity of the vehicle registration when using any certified battery.[9]

This is a significant enabling step by the government. It not only allows for decoupling the battery's upfront cost from the price of the EV, but is also an enabler for the Battery as a Service (BaaS) industry. As noted by a few industry professionals, the process of EV registration is still not very smooth as there can be glitches while registering the vehicle in the system. The official software is still not updated to handle different kinds of EV registration processes, including separate battery registration and re-registration of retrofitted ICE vehicles as EVs.

Industry expects comprehensive regulatory framework for battery swapping stations: The Ministry of Power had informed Rajya Sabha in January 2025 that the *Guidelines for the installation and operation of battery swapping and charging stations* have been issued which outlines the standards and protocols to facilitate the development of a nationwide network of battery charging stations and battery swapping stations. The industry representatives believe that the definition related to the battery swapping industry needs to be more comprehensive. This is needed to address the issues related to safety, quality, performance parameter, tax structure, operational eco-system, interoperability and standardization so that different battery types can coordinate with different swapping systems, enable data sharing and communication methods, electricity access and tariff, recycling strategy for swapped batteries and to define the scope of swapping application in all vehicle segments.

Need national- and state-level support to address high cost of swapping stations: The current national-level demand incentive programmes for EVs are designed to promote fixed charging stations. Incentives are linked with size of the batteries and are disbursed per kWh of the battery. However, swapped vehicles are sold without batteries. Financial instruments have also not matured to meet the high capital costs in these stations. Accessing long-term financing for battery-swapping models is challenging.

The 'India EV Digest 2023' by the Ministry of Power has listed the state-level support for battery swapping stations. Some of them include both financial and non-financial benefits. Setting up battery swapping stations involves substantial investment in land, equipment, and skilled personnel. Additionally, financing the battery swapping eco-system requires policy attention. Since it is a high capex business, the government may likely intervene with Viability Gap Funding to provide an impetus to the industry and help it achieve scale. Establishing a battery swapping system even for a moderate number of vehicles demands significant investment, both locally and at the power grid level.

Strengthen safety standards for battery swap stations: The Draft Battery Swapping Policy 2022—as developed by NITI Aayog—has listed a set of standards for safety and testing for cost-effective infrastructure for swapping of EV. The Ministry of Power had, in January 2025, issued guidelines governing installation and operation of battery swapping infrastructure.

Table 2: State-level support for battery swapping stations

States' notified EV policy	Nature of support for battery swapping stations
Andhra Pradesh	• Support is provided at 50 per cent of the cost of the infrastructure with limit of Rs 2 crore per swapping station. • Capital subsidy of 25 per cent of fixed capital investment up to a maximum subsidy of Rs 10 lakh for 50 swapping station is allowed. • A 100 per cent of net state GST reimbursement for the purchase of advanced batteries for swapping stations is permitted. This will be further supported by land allocation.
Bihar (draft)	• Suitable land on lease basis. • PPP Model for setting up of charging/swapping stations. • Petrol pumps will be allowed to setup charging/swapping station freely subject to such BSS qualifying fire and safety standard norms. • Robotic battery swapping arm at public bus stations. • Swapping stations at every 25 km on state /national highways in Bihar and every 3 km in the city.
Chandigarh	Subsidized EV tariff shall be applicable for BSS too.
Chhattisgarh	Public and private operators shall be invited to set up battery swapping stations across all the cities and along the national highway and state highway in phases by porting and providing locations at bare minimum rental lease.
Delhi	• Providing concessional locations at minimum lease rental. • 100 per cent of the SGST reimbursement for purchase of advanced batteries.
Goa	Provide Open Access without the condition of having contracted demand of 1 Megawatt (MW)
Haryana	• 100 per cent SGST as reimbursement for purchase of advanced batteries. • Capital subsidy of 25 per cent of Fixed Capital Investment up to a maximum subsidy of 10 lakh for 50 stations. • Buildings such as malls and other commercial buildings will be incentivized. • All petrol pumps will be mandated to have charging stations and battery banks. • Land allocation for setting up of BSS. • Facilities will be provided in the form of a kiosk to service e-2W and e-3W.
Himachal Pradesh	Subsidized EV tariff will be applicable for BSS.
Karnataka	• 25 per cent capital subsidy on equipment/machinery up to Rs 3 lakh for 2W and 3W (100 BSS); up to Rs 5 lakh for 4W (50 BSS), and up to Rs 10 lakh for bus (50 BSS). • Exemption from stamp duty. • Concessional registration charges (0.1 per cent). • 100 per cent of land conversion fee. • 100 per cent exemption of electricity duty/tax on electricity tariff. • 100 per cent of net SGST sanctioned as interest free loan. • Provide land on long lease for setting up of BSS. • To facilitate EVs on highways, BSS will be provided at every 50 km.
Kerala	• Capital subsidy of 25 per cent up to Rs 10 lakh for first 50 stations. • 150 BSS for 2W and 3W shall be set up in three major cities.
Madhya Pradesh	• Public charging systems must have standalone battery swapping facility. • At identified locations, expressions of interest will be invited through bidding to set up BSS. • Open access and Net Metering for battery swapping station with renewable energy integration.
Maharashtra	Demand incentive up to 50 per cent shall be provided to the OEM and the rest to the battery swapping energy operator
Odisha	• Location will be provided at a minimum rental lease. • 100 per cent SGST reimbursement for purchase of batteries.
Punjab	Providing locations at concessional rate for setting up battery swapping infrastructure.

States' notified EV policy	Nature of support for battery swapping stations
Tamil Nadu	• The first 200 public battery swapping stations to be set up shall be eligible for a capital subsidy of 25 per cent on the cost limited to Rs 2 lakh per station. • Subsidized EV tariff shall be applicable for battery swapping stations.
Telangana	Swapping station for every 50 km within state boundaries on highways.
Tripura	Government land on lease or rent will be available for BSS.
Uttar Pradesh	• Capital investment (excluding lad cost) of up to Rs 20 lakh. • Swapping station for every 50 km within state boundaries on highways.
West Bengal	• Providing concessional locations for battery swapping stations. • Distribution company (DISCOM) shall release supply to battery swapping stations within 48 hours of application.

Source: EV Digest 2023, Ministry of Power

BIS has drafted the IS 17896 (Part 1):2022/ IEC TS 62840-1:2016 and IS 17896 (Part 2):2022/ IEC 62840-2:2016 in 2022 on safety requirements for battery swap stations, that are to be notified. Battery swapping requires careful handling of large amounts of portable electrical energy, necessitating rigorous safety protocols. Improper handling or maintenance can increase risks of fire or explosion, posing safety hazards for the public. Safety is even more crucial in this setup compared to traditional fuel stations as stored electrical energy is not visible. Frequent battery swaps require reliable high-current connections within the battery compartment to prevent dangerous overheating or arcing in the power connections.

Battery swapping stations and access to electricity: The *Guidelines for Installation and Operation of Battery Swapping and Charging Stations* issued by the Ministry of Power on 19 January 2025 states that owners of swapping stations are permitted to use an existing electricity connection with or without seeking an increase in the connected load, in order to charge swappable batteries. It is usually stated by the industry that the minimum requirement can be in the range of 30–80 kW per swap station to charge the swappable batteries and the ancillary equipment. This may require 350–500 V for charging. If the electricity demand increases, they may be required to obtain a high-tension connection or set up a transformer to cater to the swap stations.

The draft policy includes guidelines for electricity tariffs at battery swapping stations as well. Public and captive stations that use exclusive electricity connections will follow provisions from the revised 2022 *Guidelines and Standards* for charging infrastructure for EVs. Private charging stations will be subject to tariffs set by the appropriate regulatory bodies. The policy has also introduced Time–of–Day (ToD) tariffs, which will help manage load demands on the grid and optimize swapping station operations.

The 2024 EV charging guidelines has stipulated timelines for electricity connections for EV charging stations—within three days in metropolitan areas, seven days in municipal areas, and fifteen days in rural areas. The guidelines also call for a single-window clearance process for obtaining electricity connections, along with separate billing and metering for EV stations. Public Charge Point Operators need to adopt protocols like Open Charge Point Protocol and Open Charge Point Interface, ensuring future compatibility.

10. The challenges of standardization and interoperability

As the number of BaaS providers are increasing in India, the policy conversation is shifting towards the need for standardization and interoperability of battery form factors, components and network design. This is similar to the early 2000s when phone number portability was not available in India and different telecom operators held on to their customers. Although this prevented the conditions of a monopoly, it did create inconvenience for end users. A level playing field is necessary to provide the best service and the most cost-effective plans to eventually dominate the market.

The Draft Battery Swapping Policy 2022 has proposed the standardization of battery dimensions and specifications for battery swapping in two- and three-wheeler EVs for easy and quick swapping of batteries—irrespective of the vehicle specifications.

The NITI Aayog policy has also advised the Bureau of Indian Standards (BIS) to develop a rigorous testing protocol to ensure maximum protection at the electrical interface, a self-certified and open battery management system (BMS), and a recommended approval from the Automative Research Association of India (ARAI) for relevant EVs to accept interoperable swappable batteries. These are required to address safety guidelines; Central Management System and pack dimensions, along with a connection system and communication protocol.

As mentioned earlier, Bureau of Indian Standards (BIS) has developed standards for battery pack form factors, connector systems, communication protocols, and network management for battery swapping regardless of vehicle or battery make. These standards are intended to enable facilitate seamless swapping across different vehicles and charging stations. In an interoperable ecosystem batteries from different manufacturers can be swapped at various charging stations while they all meet the safety requirements for battery swap systems.

The BIS standards also specify communication protocols between the battery management system (BMS), the EV, and the charging station to ensure proper coordination during the swapping process. Efficient network management and communication channels between the battery and the charging network can ensure seamless charging and swapping operations.

The draft standards have laid down requirements for the battery pack's dimensions, ratings, and mass, requirements for swapping along with requirements for power transfer between the battery and the battery swapping station. The Connection Systems section of this standard covers requirements for the coupler/connector, both between the battery and the swapping station and the battery and the vehicle. This standard is composite and is applicable to the battery swap system (BSS) connected to supply, with rated input supply voltage up to 415V AC, 50 Hz or up to 400V DC and SBS with a nominal voltage of 48+−5V DC and a maximum working voltage of less than or equal to 60V DC.

The draft standard for Central Management System (CMS) covers functionalities of CMS and user application that helps users to access swapping infrastructure and sets requirements of the BaaS operator platform to maintain all records.

However, this draft standard has missed specifying data privacy and cyber security requirements for EV users' personal data which will be collected by private battery swapping companies. Even the slightest possibilities of cyber breaches must be anticipated and appropriate standard operating procedures (SOPs) must be set in place to protect user data.

To avoid the inconvenience of switching between several battery swapping apps for users, there must be regulations set up for interoperability of CMS as well. It is important to prepare for possible Internet outage and create protocols for swapping, even though private companies are likely to take action in this regard.

Industry concern over standardization and interoperability: Upscaling of battery swapping requires standardized battery designs and sizes, as there are a wide range of EV models and manufacturers in the market. Achieving compatibility and interoperability among various OEMs is essential for widespread adoption. This shift would require two- and three-wheeler manufacturers to design vehicles around standardized battery forms rather than designing batteries to fit existing vehicle models. Not only will this ensure production of similar sized batteries with similar chemistries, it will also help industry benefit from scale manufacturing, thus reducing unit cost of the battery. Reduction in cost can also benefit the fixed batteries segment and the upfront cost of electric vehicles. As noted earlier, this has not progressed due to resistance from the industry.

The standardization bid soon emerged as the point of contention for the industry. The apprehension is that the standardization would unfairly benefit one particular original equipment manufacturer (OEM).[10]

Currently, manufacturers have adopted a wide range of designs and standards for EV batteries with different form factors, connectors, etc. These are based on proprietary design and customized vehicle product. This creates a more individualized market for the battery swapping providers with a captive clientele and allows them to have a committed market for timely returns. The OEMs want to maintain a strict proprietary control over their battery systems to stave off competition, which is also the most expensive part of the vehicles.

If an EV user's given service provider is not performing or shuts down, then the user will not able to switch services. It is also difficult to assure performance for the swapped batteries. Standardization of the battery form factor can allow users of different vehicle makes and models to swap their battery easily at any service station.

However, this concern is not unique to India. Even globally, interoperability and standardization are yet to take shape for implementation, except some pilot testing. Most governments are prioritizing safety standards over interoperability.

Due to strong industry opposition, the progress on interoperability has slowed down. Overall, the vehicle OEMs follow the Automotive Indian Standards under the Central Motor Vehicle Rules (CMVR) for safety and performance and the charging providers meet the guidelines of the MoP. But the standards on interoperability are on hold. It has now been left to the industry—manufacturers and BaaS providers—to develop combinations for swapping technologies.

Nonetheless, a rigid legal framework is imperative to address the issues of legality, accountability and responsibility for end-of-life batteries.

11. How can battery swapping stations enable vehicle-to-grid technologies?

There are speculations about the feasibility of having battery swap stations with low utilization of batteries. For under-utilized batteries, the vehicle-to-grid (V2G) technology has been suggested as a possible solution. This technology allows EVs to exchange electricity with the power grid in both directions. It also offers a solution to concerns about unused batteries piling up in swapping stations driven by low demand and inadequate utilization. For instance, the first battery swapping company Better Place which started operating in 2008 had a similar issue. With detailed management of load through smart charging, Time–of–Day (TOD) tariffs, load throttling and demand response schemes, idle batteries can become a source of power and deployed for peak shaving and can help with grid balancing and load stabilization.

V2G can enable battery swapping by allowing EVs to act as a mobile energy storage system. A large number of EVs on the road can provide a ready-made infrastructure and V2G can monitor and allow EVs to be recharged, discharged and connect to the grid at different times and locations as per requirement. To optimize the use of charged batteries at battery swapping stations, they could be utilized to supply power back to the grid during times of insufficient supply. This concept, known as vehicle-to-grid (V2G) power transmission, has already been demonstrated in various cases, such as families in the US using their EV batteries to power their homes during grid outages. However, enabling V2G requires considerable engineering effort.

The V2G technology operates like a hub which can also schedule swaps. When an EV requests a battery swap, relevant information is sent to a scheduling centre. The scheduling centre can then recommend which battery swapping station (BSS) to use.

V2G technology works by using bidirectional charging stations to push and pull energy between the grid and connected vehicles. The amount of energy that can be exported and when it can be exported can be customized by the owner. It can help balance the supply of electricity with the demand by storing excess energy in EV batteries and return it to the grid when needed. It can also minimize costs by enabling EV owners and network providers to coordinate charging patterns.

12. How can swapping stations efficiently manage electricity and thermal requirements?

Swappable batteries are designed with built-in safety features, including a battery management system (BMS) and thermal cut-off mechanisms. These systems prevent the battery from reaching dangerous temperatures, ensuring the safety of both the battery and the station. Network operators avoid fast charging to prevent excessive heat build-up. The charging profile used by battery swapping stations is typically around 0.5C, which is slow enough to avoid reaching thermal runaway conditions.

Regarding electricity supply, partners who own the franchisee stations are responsible for obtaining the electricity connection and paying utilities. Battery swapping network operators do not manage the electricity contracts directly; instead, the franchisee partners handle these logistical responsibilities, including securing electricity connections, real estate, and following SOPs. Battery swapping stations generally require less than 50 kW of sanctioned power so additional infrastructure is usually not necessary. Many franchisees also install EV meters provided by their local distribution companies (DISCOMs) to monitor electricity usage.

13. How can battery swapping service providers safely collect user data?

Battery swapping providers use proprietary software to collect data via two-way communication with smart devices in batteries. Key uses of this data include:

Safety monitoring to detect tampering and provide alerts.
- Battery health prediction to assess State of Health (SOH) and trigger warranties.
- Network planning to optimize battery distribution based on customer patterns.
- Providers use this data to geofence batteries and identify where demand for swapping is highest, ensuring stations are within 10 km of customers, reducing wait times, and maximizing battery utilization.
- Electricity and thermal management at swapping stations

Battery swapping service providers rely heavily on data, which is at the core of their operations. Most of these providers develop proprietary software in-house to manage and monitor their networks. The batteries are equipped with smart devices that allow for real-time communication, collecting data on their status and location. These devices enable two-way communication and geofencing, allowing the provider to track the last charge details of each battery to ensure that batteries are only charged at authorized swapping stations.

If a battery is suspected of being at risk of theft, the service provider can remotely disable it, preventing it from charging or discharging. Additionally, these providers use predictive analytics to forecast when and where batteries will need to be swapped. If a battery is not swapped within a certain timeframe, it is flagged as potentially at risk for pilferage. In such cases, the provider will first attempt to contact the customer; if unreachable, the battery can be remotely disabled. Third-party agencies may also be engaged to locate the missing battery.

Data is the backbone of battery swapping services as managing a large-scale network of 900 stations and 100,000 batteries for a company such as Battery Smart, for instance, would require constant oversight. Providers generate vast amounts of data, with about 2.5 million rows of data generated every 15 seconds.

This data includes parameters such as cell-level voltages, temperatures, current profiles, and geolocation information of each battery. The data is used in three primary ways:

Safety and security: Data is used to prevent theft and to trigger critical alerts for potential issues with the assets.

State of Health (SoH) prediction: The data helps predict battery life, the number of remaining charging cycles and how the battery's performance is deteriorating, enabling the service provider to manage warranties and maintenance.

Network planning: This is the most comprehensive use of data, which allows providers to optimize their network.

14. How does battery residual value influence EV financing and affect the industry?

Despite the growing attention to EVs, financing remains a challenge mainly because of the uncertainty around residual value of the vehicle. As with any depreciable asset, the value of an EV reduces with time. Typically, interest rates increase with increased uncertainty and risk associated with end-of-life value of the asset. Therefore, it is important for the financier to be aware of a method to calculate end-of-life value or residual value of an EV before disbursing a loan or insurance.

Uncertainty around battery residual value complicates EV financing, as lenders seek clarity on the end-of-life value of the battery, which constitutes at least 40 per cent of the EV's cost. Residual value is typically gauged by assessing the battery's State of Health (SoH)—its current max charge capacity as compared to when the battery was new. Battery degradation follows a pattern where, after steady declines, capacity suddenly drops at 60–70 per cent of its cycle life (the 'knee point'), which researchers are attempting to predict using data models. Additionally, advancements in battery thermal stability, following previous fire incidents, have improved confidence among financiers.

15. Are bespoke insurance products available for the battery swapping industry?

The insurance market for battery swapping in India is still in its early stages with limited development. Insurers have cited the lack of comprehensive data on batteries as a barrier to offering specific coverage for this sector. Even Battery Smart, a significant player in battery swapping, has yet to secure insurance for its batteries and swapping stations. In April 2024, Battery Smart provided health and accidental coverage[11] for its drivers and station partners but not for the batteries or stations themselves.

While dedicated battery-swapping insurance remains unavailable, there are insurance options for private EV charging stations and fleet aggregators. However, these policies often classify EVs similar to internal combustion engine (ICE) vehicles. Companies like Zuno General Insurance (formerly Edelweiss General Insurance)[12] offer policies for private charging stations.

As EV adoption continues to accelerate, insurance solutions for batteries, charging stations, EVSE, and battery swapping infrastructure have yet to keep pace in India.

16. End-of-life management: How will swapped battery waste be recycled?

The management of swappable battery waste is closely linked to the battery management system (BMS) used by swapping stations. It is crucial to track battery performance throughout its lifecycle, from usage to end-of-life, to assess its potential for reuse or recycling. As India develops its secondary battery market, improving access to BMS data is essential for creating a reliable market for used batteries.

The NITI Aayog 2022 report has estimated that 128 Gigawatt hours (GWh) of retired batteries will be available for recycling by 2030, with significant potential for stationary energy storage. Recycled materials will be used in the production of new batteries, with specific targets set for the recovery of valuable materials like lithium, cobalt, and nickel.

The Battery Waste Management Rules 2022 sets the framework for the safe disposal and recycling of EV batteries. Manufacturers must set up collection centres for used batteries and meet annual collection targets. These rules aim for a 90 per cent recovery rate of battery materials by 2026–27 and require that recycled materials make up an increasing percentage of new battery cells.

17. Global action on battery swapping

The battery swapping industry and market are evolving globally. These initiatives have primarily been initiated by industry pilots driven by a handful of players. There are regional differences. The markets in developing countries are dominated by two- and three-wheelers and small vehicles. The advanced markets of Europe and the US have focused more on cars. China has the most substantial market where swapping has been adopted across all vehicle segments—two-wheelers, cars, buses and trucks.

While there are policy conversations globally around interoperability and standardization, it is yet to take shape. Majority of the countries have prioritized safety standards over the interoperability aspect of the battery swapping ecosystem.

The swapping market is expected to grow manifold in China. In China, the national new energy vehicles (NEV) purchase subsidy and purchase tax exemption policy have provided for fiscal and non-fiscal incentives, and supports for infrastructure, R&D and pilot projects for implementation of battery swapping programme. This programme has targeted two-wheelers, taxis and ride-hailing vehicles as well heavy-duty buses and trucks. A large focus of this programme is on trucks and promoting swapping in logistics, ports and mines and public transport.

In India, the focus remains on developing adequate and stringent safety regulations like the National Standard for Battery Swap Safety Requirements for Electric Vehicles that outline the safety protocols and testing systems for battery swappable EVs. However, interoperability regulations are not being discussed at the moment.

A quick glance across the world brings out similar trends. In the US, battery swapping has already begun in the car segment with a few companies taking the lead. However, the US does not have explicit policies on battery swapping as it is not considered an established technology.

Similarly, in Europe, there are neither regulations nor subsidy for battery swapping in spite of the market growing rapidly. However in the European Union (EU), 'battery passport' regulations were introduced in 2023. The 'Regulation

2023/1542', replaced the previous Battery Directive (2006/66/EC) that states new sustainability and safety requirements for batteries and battery-operated products. This regulation requires detailed information about the lifecycle of batteries to be digitized, enhancing transparency, traceability, circularity and sustainability in the form of digital product passports or 'battery passport'.

Starting 18 February 2027, the batteries of Light Means of Transport (LMT), Electric Vehicle (EV), and industrial batteries above 2 kWh sold in the EU will need electronic registration via a 'battery passport', featuring a QR code and CE marking for unique identification. This will track the lifetime and life cycle of the batteries. This will have bearings on any swapping strategy as well. This will enable battery swapping stations to track battery details like location, state of charge (SOC), and state of health (SOH), and would streamline battery swapping operations and encourage EV adoption by lowering upfront EV costs. Additionally, the battery passport would disclose ESG practices, helping consumers support sustainable choices and encouraging ethical battery production.

In Asia, Japan has made major advancements in battery-swapping technology with a sizeable market share. Government subsidies are also available for swappable vehicles. Currently, none of the governments have implemented interoperability. But they have prioritized safety standards.

18. What needs priority attention in the next phase?

Battery swapping strategy is an opportunity for upscaling electrification especially in the developing markets that are more price sensitive and upfront capital costs can be a barrier to building rapid scale. This market has begun to progress even before the regulations could be fully developed. But this market needs to be governed by well thought out policies are regulations to maximize productivity, safety and performance. This requires some priority measures:

1. Need comprehensive battery swapping policy to define the scope of application across vehicle segments; requisite safety, performance and interoperability standards; cohesive and harmonized set of regulations for battery swapping stations, and their requisite audits.

2. Strengthen safety parameters for battery swap stations.

3. Address issues related to homologation and registration of vehicles without batteries and batteries at the point of registration.

4. Develop phased approach to interoperability and standardization and define the technical and communication protocol accordingly to address multiple applications and operative approaches. Additionally, address issues related to innovation, safety and liability.

5. Develop fiscal incentives and financial instruments to support the high capital investments similar to the ones provided for fixed charging stations. Rationalize GST and other taxes to reduce costs.

6. Align requirement of battery swapping industry with Battery R&D roadmap on future battery chemistry, battery efficiency, etc. apart from skill development.

7. Promote integration of battery storage in swapping stations with the grid and grid services. Regulate bidirectional energy flow to support grid stability and renewable energy integration.

References

1. Winton, Neil, September 2022, "Battery-Swapping Revival Could Threaten Electric Car Charging Networks", Forbes, Available at https://www.forbes.com/sites/neilwinton/2022/09/12/battery-swapping-revival-could-threaten-electric-car-charging-networks/?sh=340e89d21b1b, as accessed on 6 November, 2023

2. Renga, Daniela, et al., October 2022, "Renewable powered Battery Swapping Stations for sustainable urban mobility", IEEE, Available at https://ieeexplore.ieee.org/document/9921757 as accessed on 18 November, 2024

3 Ahmed, Alam et al, May 2020. "Battery swapping station for electric vehicles: opportunities and challenges", IET. Available at https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/iet-stg.2019.0059, as accessed on 18 November, 2024

4. Newsletter, 2021, Sweden-China Bridge—Collaborative Academic Platform for the Electrification of Transportation Systems, No.3, August, https://www.hh.se/download/18.38f604db17cdbca68f648bc3/1635846507778/Sweden-China%20Bridge,%20Newsletter%203,%202021-09-10%5B19%5D.pdf

5. Hongyank Cui eta al. August 2023, ICCT. "China is propelling its electric truck market by embracing battery swapping"; available at https://theicct.org/china-is-propelling-its-electric-truck-market-aug23/ as accessed on 18 November, 2024

6. India Battery Swapping Association, http://ibsa.org.in/#:~:text=IBSA%20is%20also%20working%20with,of%20purchasing%20batteries%20is%20separated.

7. REGlobal 2024, EV charging infrastructure and battery swapping in India; 2 September, 2024 | Mega Trends & Analysis, https://reglobal.org/powering-india-ev-charging-infrastructure-and-battery-swapping/#:~:text=Nonetheless%2C%20the%20future%20outlook%20for,Trade%20Promotion%20Council%20of%20India

8. Ministry of Power, 2024, India EV Digest 2023, https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/mar/doc202431317801.pdf

9. Anon. April 2022, "Battery Swapping Policy", NITI Aayog, Available at https://www.niti.gov.in/sites/default/files/2023-03/20220420_Battery_Swapping_Policy_Draft_0.pdf as accessed on 30 October, 2023

10. Goled, Shraddha, July 2023, "India's battery swapping policy for electric vehicles: A timeline", Techcircle, Available at https://www.techcircle.in/2023/07/04/a-timeline-proposal-of-battery-swapping-scheme-to-demand-for-redraft as accessed on 21 September, 2023

11. Anon. April 2024, "Bharatsure Partners With Battery Smart To Provide Insurance Coverage To Drivers And Station Partners", Outlook Business, Available at https://www.outlookbusiness.com/corporate/bharatsure-partners-with-battery-smart-to-provide-insurance-coverage-to-drivers-and-station-partners as accessed on Sep 12, 2024

12. Das, Neelanjit, November 2023, "Damage to EV battery, charging station while charging: Insurer launches insurance covers for this", The Economic Times, Available at https://economictimes.indiatimes.com/wealth/personal-finance-news/damage-to-ev-battery-charging-station-while-charging-insurer-launches-insurance-covers-for-this/articleshow/105420463.cms?from=mdr as accessed on 12 September, 2024

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