

EV battery swapping

Number 54, 2026

Part of the [Tranzinfo Hot Topics series](#), this issue offers a selection of recent material on EV battery swapping, a technology that offers an alternative to charging batteries inside the vehicle with a cable. Early attempts at battery-swapping stations failed when they first emerged [nearly two decades ago](#), but recently there has been a resurgence of interest and a new generation of battery-swapping services has emerged across China, Europe, and the US.

EV battery swapping promises to be a solution to long charging times and range anxiety for EV drivers, allowing them to swap depleted batteries for fully-charged ones in a fraction of the time it would take to charge a battery. They also provide hope to urban EV owners without access to home charging facilities.

[Targeted uses](#) where the technology could be highly beneficial include fleet vehicles, commercial vehicles, taxis, and ride-hailing services, where minimizing downtime is critical. The technology is also being used successfully across Asia for micromobility devices such as [e-scooters](#), and is already being used extensively for heavy vehicles in [China](#) and trialled [elsewhere](#).

[Challenges](#) include: a lack of standardisation/interoperability in battery pack design; the high infrastructure costs to build the stations; the logistics involved in location planning and battery supply; and consumer acceptance.

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Overview

[Charging may be out and battery swapping in](#)

Berry, L. Inner East Review, 17 February 2026

Chinese carmaker Nio hit a milestone recently, swapping 146,649 batteries in a single day, highlighting the ease of use and popularity of the new technology, which could be the answer to long EV charging times.

[Battery swap for 40-tonne trucks: eHaul project unlocks alternative to conventional charging stations](#)

Electrify, 19 January 2026

A German trial of automated battery swapping for heavy-duty electric commercial vehicles concluded that the procedure is possible within a few minutes in real-world conditions.

[A new fully charged EV battery in five minutes: Are China's swap stations the future of electric cars?](#)

BBC News, 6 May 2025

China has been trialling battery swaps for electric cars for years. Are they a viable solution to range anxiety?

[Is battery swapping a viable alternative to charging in Australia?](#)

EV, 2 August 2025

Popularised by Chinese automakers like NIO and gaining momentum in parts of Asia and Europe, battery swapping allows drivers to replace a depleted battery with a fully-charged one in minutes — without waiting for traditional charging. But is this model viable for Australia?

[The rebirth of EV battery-swapping services and why their time is now](#)

Forbes, 15 April 2024

A new generation of EV battery-swapping services has emerged in recent years as the EV market size approaches a critical threshold. The inconvenience of EV charging for many drivers, particularly those in urban areas, has sparked renewed interest in EV battery-swapping services.

[What you need to know about battery swapping](#)

Kollner, C, Springer Professional, 12 March 2024

The Chinese electric car manufacturer Nio is now also operating its stations for automated battery swapping in Europe. Swapping instead of charging is the motto. What's behind the concept? Everything you need to know at a glance.

[It works for scooters: can battery swapping work for electric cars?](#)

Forbes, 28 January 2024

As battery swapping stations for e-scooters become more common across Asia, some carmakers are beginning to look more closely at the battery swap idea for EVs.

[Australian start-up launches first solar-powered battery swap station](#)

The Driven, 11 December 2024

Janus Electric, a New South Wales based start-up that has developed technology to electrify trucks and use swappable batteries, has unveiled its first solar-powered battery swap station at the Moorebank Intermodal Precinct in Sydney, where 2-metre by 1.2-metre batteries can be swapped in just four minutes.

[Five-minute recharge: China's Nio rolling out new electric-car battery swap stations in Europe and UK](#)

Drive, 21 May 2023

Chinese electric vehicle maker Nio is planning to roll out new automated battery-swap stations that can install a fully-charged unit in under 3 minutes, with the full process – including car alignment and safety checks – taking less than five minutes.

[Battery-swapping revival could threaten electric car charging networks](#)

Forbes, 12 September 2022

There is a strong case to be made for battery swapping as a way to recharge electric vehicles quickly, according to experts.

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In-depth

[Game changer or costly innovation? A cost competitiveness assessment of battery-swappable electric vehicles](#)

Adu-Gyamfi, G, Hao, Y, Asamoah, AN, Nketiah, E, Obuobi, B, & Gan, H
Transportation Research Part D: Transport and Environment, vol. 149, p. 105056, 2025

Battery-swappable electric vehicles (BSEVs) enhance convenience and driving range by enabling quick battery replacement. However, their total cost of ownership and competitiveness have not received research attention. Consequently, this study employs 5- and 10-year total life cycle cost methodology to evaluate the ownership cost and competitiveness of BSEVs with battery electric vehicles (BEVs) and internal combustion engine vehicles (ICEVs). Results revealed that in five years, though BEV-sedans are the most cost-competitive, BSEV-sedans reached near-parity with BEV-sedans and outperform ICEV-sedans. For SUVs, BSEVs only achieved parity with ICEVs. In 10 years, BSEV-sedans reached near-parity with BEV-sedans and ICEV-sedans. In SUVs, BEVs stayed cost-effective, but BSEVs matched ICEVs with a slight edge. Under battery replacement, BSEVs emerged as the most cost-competitive, reaching parity with BEVs and moving from a cost deficit to surplus in both vehicle categories. The study recommends potent strategies to ensure the economic attractiveness of BSEV for sustainable mobility.

[Battery swapping station for electric vehicles: opportunities and challenges](#)

Ahmad, F, Saad Alam, M, Saad Alsaidan, I, & Shariff, SM, IET Smart Grid, vol. 3, no. 3, pp. 280–286, 2020

Recent research and development have been focusing on designing battery swap station (BSS) architecture with the prospect of providing a consistent platform for large-scale fleets of hybrid and electric vehicles (i.e. xEVs). The BSS may calibrate its subsystem for electric vehicle (EV) deployment by following the example of existing gasoline refuelling stations, in which the discharged batteries are being replaced or swapped by partially or fully

charged ones in a few minutes. This work is an introduction to BSS including infrastructure, techniques, benefits, and key challenges associated with BSS.

[Electric vehicle battery swap stations: an overview and critical review](#)

Alhazmi, YA, Journal of Umm Al-Qura University for Engineering and Architecture, 2025

Battery Swap Stations (BSS) are one of the more recent alternatives to conventional plug-in charging that hold solutions to issues of battery degrading, range anxiety, and extended recharging time. Grounded on the five most critical objections to mass deployment—infrastructure requirements, interoperability and standardization, consumer behavior and marketplace receptiveness, security and regulation, and technology viability in the context of changing trends, this review paper offers a comprehensive and in-depth analysis of BSS. The study analyzes the financial and technological aspects of BSS, takes account of environmental and regulatory matters, and covers actual implementations in China and India based on tapping into a large body of recent literature. The evidence suggests that although strategic use of BSS, especially for shared mobility, commercial fleets, and energy integration, is valuable, its mass use still hinges on overcoming standardization barriers, harmonizing policy incentives, and developing cooperative industry structures. Concluding from the review findings, BSS may be a future-proofing and complementing component of the global EV ecosystem and not a palliative.

[Battery swapping stations as grid interactive energy assets: design, operation, and applications in electric mobility systems](#)

Borgosano, S, Longo, M & Zanielli, D, SSRN, 12 February 2026

The rapid growth of Battery Electric Vehicles (BEVs) is increasing the pressure on conventional charging infrastructures, highlighting the need for fast, scalable, and grid compatible energy replenishment solutions. Among the emerging alternatives, Battery Swapping Stations (BSSs) have re-emerged as a promising complement to plug-in charging, enabling near instantaneous restoration of vehicle range while decoupling battery charging from vehicle operation. This paper provides a comprehensive review of BSS technologies, focusing on their system architectures, operational strategies, swapping modes, and associated business models. Beyond their role in electric mobility, BSSs are examined as grid interactive energy assets, capable of centralized battery management, flexible charging control, and bidirectional power exchange with the electricity system. The review analyzes Grid to Battery (G2B), Battery to Grid (B2G), and Battery to Battery (B2B) operating modes, highlighting the potential of BSSs to provide energy storage, peak load mitigation, and ancillary services, as well as to support the integration of renewable energy sources. The discussion is extended to economic and regulatory aspects, including battery as a service schemes, market participation, and large scale deployment challenges such as demand uncertainty, battery standardization, and infrastructure investment. Overall, this review positions Battery Swapping Stations not only as enabling

infrastructures for high utilization electric mobility applications, but also as flexible components of future power and energy systems.

[Charging or Swapping? A study on the private Consumers' acceptance of the electricity replenishment mode of new energy vehicles](#)

Chen, Z, Xia, S, Shao, Z, Gu, Z, Wu, Z, Wu, L, & Wang, X, Transportation Research Part F: Traffic Psychology and Behaviour, vol. 107, p. pp 903-923, 2024

In recent years, two types of electricity replenishment modes of new energy vehicles (NEVs) have gradually developed in the NEVs market: one is the battery charging mode, and the other is the battery swapping mode. These two electricity replenishment modes have their own advantages and disadvantages, and consumers have different usage experiences. Generally speaking, the battery charging mode is usually more economical than the battery swapping mode, and its usage scenarios are more common, but in terms of replenishment speed and convenience, the battery swapping mode has obvious advantages. Based on the unified theory of acceptance and use of technology (UTAUT) model, this paper tries to explore the key impact factors on private consumers' acceptance of the electricity replenishment mode of NEVs in the market, investigate the heterogeneity of gender, age, and income, and justify the development trend of the electricity replenishment mode of NEVs, aiming to provide managerial insights and policy implications for the high-quality development of the electricity replenishment mode of NEVs. The results indicate that among the five-dimensional variables the authors selected, performance expectancy has little effect on acceptance, while effort expectancy, social influence, and quality sensitivity have a positive impact on acceptance, and perceived risk has a negative impact on acceptance. Gender, age, and income level had different effects on each variable. This has relevance for the follow-up production and marketing of related enterprises.

[Charging autonomous electric vehicle fleet for mobility-on-demand services: Plug in or swap out?](#)

Gao, J & Li, S, Transportation Research Part C: Emerging Technologies, vol. 158, p. 104457, 2024

This paper compares two prevalent charging strategies for electric vehicles, plug-in charging and battery swapping, to investigate which charging strategy is superior for electric autonomous mobility-on-demand (AMoD) systems. To this end, the authors use a queueing-theoretic model to characterize the vehicle waiting time at charging stations and battery swapping stations, respectively. At the planning level, the authors find that when choosing plug-in charging, increased charging speed leads to a transformation of infrastructure from sparsely distributed large stations to densely distributed small stations, while enlarged battery capacity transforms the infrastructure from densely distributed small stations to sparsely distributed large stations. On the other hand, when choosing battery swapping, both increased charging speed and enlarged battery capacity will lead to a smaller number of battery swapping stations. At the operational level, the

authors find that improved charging speed leads to increased TNC profit when choosing plug-in charging, whereas improved charging speed may lead to smaller TNC profit under battery swapping. The above insights are validated through realistic numerical studies.

[Unlocking the potential of battery charging and swapping stations: achieving fully flexible operation via B2X and V2X integration](#)

Güldorum, HC, Diaz-Cachinero, P, Muñoz-Delgado, G, & Contreras, J, IEEE Transactions on Transportation Electrification, vol. 11, no. 5, p. pp 11041-11053, 2025

The expansion of battery swapping stations (BSSs) for electric vehicles (EVs) is attracting research interest for their capability to swiftly replace depleted batteries, mitigating range anxiety for EV users, and their potential to supply power to the distribution system (DS). As EV adoption grows, an increase in both BSSs and charging stations (CSs) is anticipated. This study introduces a novel concept for the battery charging and swapping stations (BCSSs) offering both charging and swapping services to EVs, alongside ancillary DS support and a variety of flexibility sources. The proposed mixed-integer linear programming (MILP) model seeks to maximize station owner's profits by optimizing revenues from EV services and energy sales to the DS, including battery-to-grid (B2G) and vehicle-to-grid (V2G) transactions, while considering costs associated with battery degradation and unmet service requests. The model also contains photovoltaic (PV) generation and enhances EV user satisfaction and station profitability through diverse energy transfer services, such as battery-to-battery (B2B), battery-to-vehicle (B2V), vehicle-to-vehicle (V2V), and vehicle-to-battery (V2B). The proposed model also considers the time-varying electricity tariff. Simulation results over a 24-h period with 15-min intervals reveal that the battery-to-everything (B2X) and vehicle-to-everything (V2X) flexibility services significantly improve EV satisfaction and mitigate profit loss during high-demand periods, thus greatly improving station versatility.

[A comprehensive review on electric vehicle battery swapping stations](#)

Hussain, MT, Afzal, AB, Thakurai, AH, Azim, A, Khan, RA, Alrajhi, H, Khalid, MR, & Hameed, S, in RN Shaw, P Siano, S Makhilef, A Ghosh, & SL Shimi (eds), Innovations in Electrical and Electronic Engineering, Springer Nature, Singapore, pp. 317–332, 2024

This paper comprehensively reviews electric vehicle (EV) battery swapping stations (BSS), an emerging technology that enables EV drivers to exchange their depleted batteries with fully charged ones at designated stations. The paper aims to comprehensively understand BSS's technical, economic, and environmental aspects and its potential for widespread adoption. The review covers BSS design, operation, and maintenance, including the necessary infrastructure, battery management systems, and safety protocols. It also analyzes the economic viability of battery swapping compared to other charging technologies, taking into account factors such as capital and operational costs, revenue streams, and return on investment. Further discusses the environmental impact of battery swapping, including the

potential reduction in carbon emissions, energy consumption, and resource depletion. Finally, the study examines the current state of BSS, including market trends, regulatory frameworks, and stakeholder engagement. The review concludes that BSS holds significant promise as a sustainable and convenient solution for EV charging. Still, several challenges remain to be addressed, including standardization, interoperability, and consumer acceptance. The findings of this study provide valuable insights for policymakers, industry stakeholders, and researchers working on the development and deployment of EV BSS.

[User acceptance of battery swapping in battery electric vehicles among private users in Germany](#)

Kegel, J, Wiesenthal, J, Welling, M, Kapse, A, Hirschl, B, & Sauer, DU, npj Sustainable Mobility and Transport, vol. 2, no. 1, p. 27p, 2025

The market ramp-up of battery electric vehicles (BEVs) continues to falter in Germany. One reason is user acceptance for BEVs, mainly due to insufficient range, inadequate charging infrastructure, and excessive costs. Many of these obstacles could be addressed through battery swapping stations. This study validates existing barriers to e-mobility, investigates whether battery swapping could alleviate existing barriers, and identifies potential concerns associated with battery swapping. This study is based on an online questionnaire completed by 1902 individuals representative of the German population. Results indicate that individuals interested in BEVs particularly recognize battery swapping as a problem solver. BEV owners also recognize the potential of swapping but have fewer concerns regarding e-mobility in the first place. A discrete choice experiment embedded in the survey revealed a willingness to pay an additional €56 per month for a BEV with swapping technology compared to a BEV with an integrated battery.

[Battery-swapping for heavy duty vehicles : a feasibility study on up-scaling in Sweden](#)

Nåbo, A, Abrahamsson, M, Bhatti, HJ, Björklund, M, Daniels, D, Danilovic, M, Haugland, P, Huddén, P, Portinson Hylander, J, Käck, S, Lindahl, P, Lihua Liu, J, & Sallnäs, U, Swedish National Road and Transport Research Institute (VTI), 2024

The report focuses on the commercial feasibility of a battery-swapping system for heavy trucks in Sweden. By studying business models, the compatibility with Swedish regulations, and integration into transport operations, we explore how disruptive technologies, ecosystem effects, and circularity could enable a rapid introduction and diffusion of a battery-swapping system. A special focus is on China, covering the status of battery-swapping there and analysing the processes that have led to its rapid development and deployment. In China, battery-swapping creates a new business model where actors from energy production, battery manufacturing, and the mechanical industry spearhead the development and diffusion of the technology. Battery-swapping is now the dominant technology for electric trucks in China. Advantages of battery-swapping include: only a few minutes battery swap time, reduced investment for truck owners, low impact on the

local power grid, and separation of vehicle and battery life cycles. A simulation study in this report shows that battery-swapping for heavy trucks in harbour operations could offer clear advantages compared to cable charging. However, there are several challenges to introducing battery-swapping in Sweden. First, it has no clear promoters in the industry. Swedish and European vehicle manufacturers are hesitant because it challenges their current business model, and that they may instead take the role of gatekeeper. Second, current standards and regulatory frameworks for vehicles and energy systems in Sweden and in the European Union do not include battery-swapping. The report also addresses the need for knowledge and training of people at battery-swapping stations, and the importance of social sustainability in the electrification of heavy vehicle transport operations.

[Techno-economic framework for electric vehicle battery swapping stations](#)

Tarar, MO, Hassan, NU, Naqvi, IH, & Pecht, M, IEEE Transactions on Transportation Electrification, vol. 9, no. 3, p. pp 4458-4473, 2023

Electric vehicle (EV) battery swapping stations (BSWSs) are an important aid in rapid transport electrification, especially in developing countries where per capita income is low and expensive battery prices discourage EV penetration. Consequently, a BSWS model, where the BSWS owns the battery, can help in EV penetration and rapid transport electrification. This article presents a new EV BSWS model to obtain a suitable tradeoff between the swapping time and the quality of battery health indicators. The state of charge (SOC), battery abuse, and battery degradation are measured/estimated online, while the state of health (SOH) is determined offline. The cost of the swapping cycle is determined by considering multiple cost components and penalties. The modeling approach not only enables determining a fair and affordable price for each swapping cycle for EVs but also helps keep a check on the battery's SOH and remaining useful life (RUL) during swapping without significantly increasing the battery swapping times compared with the average refueling time of internal combustion engine (ICE) vehicles. The swapping cost of the BSWS model is also compared with home and commercial charging station (HCS and CCS) models under different assumptions. The analysis suggests that the battery can be swapped in 6 min for light vehicles, comparable to the complete tank refueling of ICE vehicles. Moreover, with appropriate consideration of EV opportunity profit (EVOP), the BSWS remains feasible compared with HCS and CCS even at a high-profit margin of 750%. Also, battery degradation is considered using the economic model's degradation cost component, and its link with different SOC strategies is explored. Again, the results suggest that SOC strategies can be a helpful way for BSWS to maximize battery life and increase its profits. Moreover, considering EVOP along with battery degradation and SOC strategies further highlights the feasibility of BSWS.

[Why we need battery swapping technology](#)

Vallera, AM, Nunes, PM, & Brito, MC, Energy Policy, vol. 157, p. 112481, 2021
Energy and transport must lead the transition to a low-carbon economy, weaning their dependence on fossil fuels via massive renewable generation

and electrification of transport. A major challenge is the power system imbalance between generation and demand due to the higher fraction of non-dispatchable renewable generation such as solar photovoltaic or wind. Electric mobility will lean heavily on the power system but may contribute to mitigate the imbalance problem. This work focuses precisely on the impact of different models for future road mobility in a decarbonized power system, ranking the merits of each solution. The models considered are plug-in, plug-in and catenaries, plug-in and hydrogen, and battery swapping. We show that battery swapping, the least studied model so far, is superior to the other three in all semi-quantitative criteria of merit. We conclude our analysis with implications for energy policy and examples of public policies that could boost the adoption of this model, which has huge implications both for the mobility industry and for power systems.

[EV battery swapping back on the agenda: But how do thermal management connections work?](#)

VASA, 24 April 2024

Swappable batteries offer a practical solution to the challenges of ageing battery degradation by making it easier to inspect them while off the vehicle. If a swapped battery is found to be faulty, it can be effortlessly removed from the system and sent for repairs, often without the customer even being aware of the issue. This effectively addresses concerns regarding range degradation and greatly enhances the lifespan and residual values of EVs.

[The battery-swapping revolution: Exploring user preferences in electric micro-mobility sector](#)

Zhang, F, Lv, H, Kuai, C, & Feng, T, Transportation Research Part A: Policy and Practice, vol. 194, p. 104416, 2025

Battery swapping services (BSS) offer innovative solutions to address the challenges of charging, safety, and battery management for electric micro-mobility vehicles (EMVs), such as electric bicycles and mopeds. However, the preferences and willingness to pay (WTP) for BSS among EMV users remain uncertain. This study examines consumer preferences for battery-swapping versus rechargeable EMVs within the Chinese market, identifying key factors that influence user choices. The authors employ a Stated Preference (SP) approach combined with a hybrid choice model (HCM) to assess both the economic viability and psychological impacts, including risk perception and social influence. Key findings demonstrate a higher willingness to pay for battery-swapping EMVs due to reduced charging time and enhanced safety features.

[Strategic investment in electric vehicle charging service: Fast charging or battery swapping](#)

Zhang, Y, Wang, X, & Zhi, B, International Journal of Production Economics, vol. 268, p. 109136, 2024

With the increasing adoption of electric vehicles (EVs), there is a growing need for public charging infrastructure. As a result, significant investments have been made in charging services, particularly, fast-charging (FC) and

battery-swapping (BS) services. This paper examines the impact of technical and operational factors, as well as market conditions, on the pricing and profitability of each service to explore whether and how EV charging service providers should invest in these emerging charging services. The analysis with benchmark to private-use slow-charging (SC) services reveals that if the valley electricity price is high and the potential market size is small, lowering service costs does not make BS services a viable option. When the valley electricity price is low, reducing battery loss will not give FC services an advantage. However, in such scenarios, BS services can gain an edge by decreasing service costs. Interestingly, even if both SC and BS services are negatively affected by higher valley electricity prices, the impact on the profitability of BS services is more severe. The authors' results provide implications for the development of public EV charging service infrastructure. The authors recommend that implementing energy storage solutions can help alleviate the negative consequences of escalating valley electricity prices and wider peak–valley electricity price differences on BS services and FC services, respectively.

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