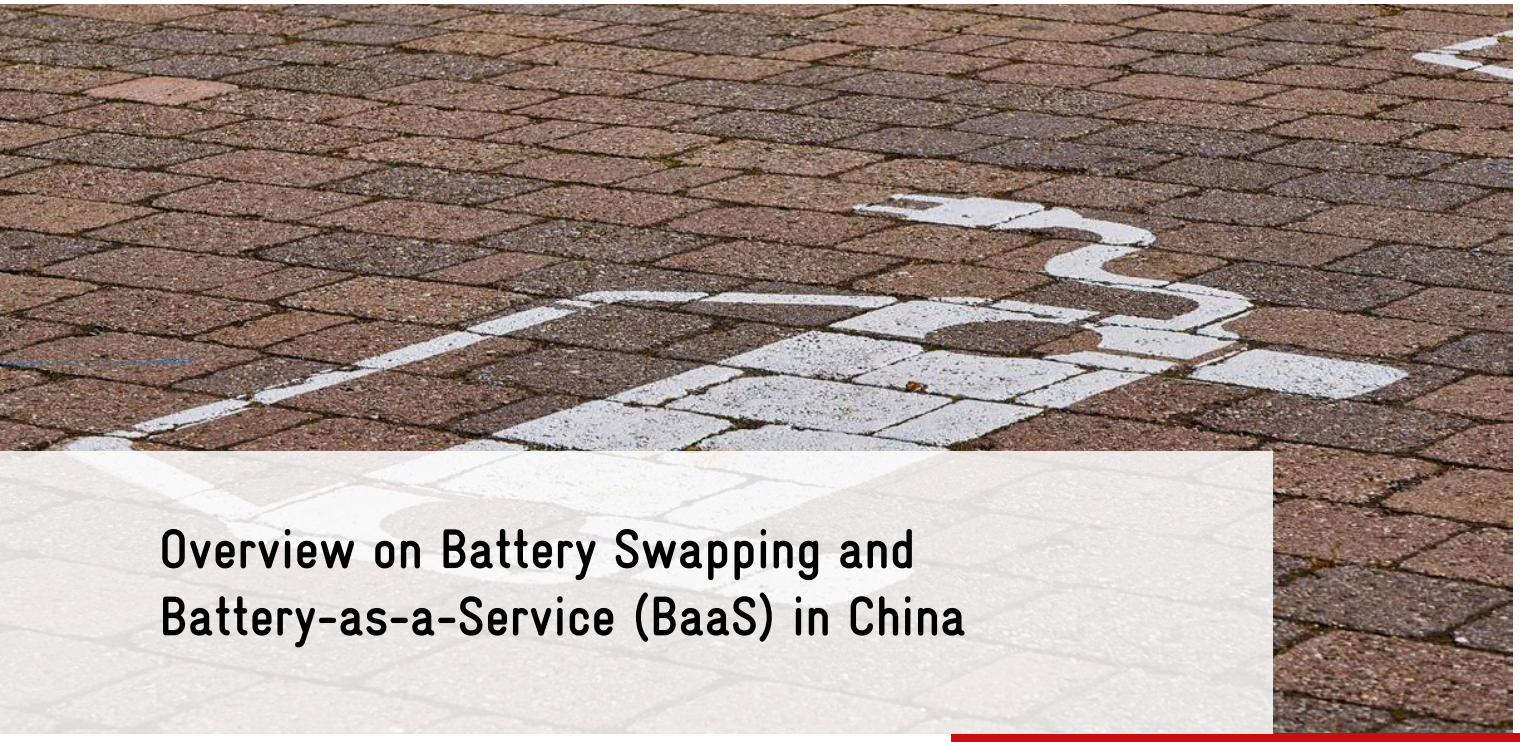

Overview on Battery Swapping and Battery-as-a-Service (BaaS) in China

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Registered offices
Bonn and Eschborn, Germany

Address
Tayuan Diplomatic Office Building 2-5
14 Liangmahe South Street, Chaoyang District
100600, Beijing, PR China
T +86-(0)10-8527 5589
F +86-(0)10-8527 5591

E transition-china@giz.de
I https://transition-china.org/mobility

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Responsible
Sebastian Ibold (GIZ)

E transition-china@giz.de
I https://transition-china.org/mobility

Authors
vSebastian Ibold (GIZ), Yun Xia (GIZ)

Layout
Xin Hu (GIZ), Ke Zhang (GIZ)

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Beijing, 2022

Content

Background

Electric Vehicles (EV or New Energy Vehicles or NEVs[1]) and in particular battery electric vehicles are widely seen as the key to making transport sustainable and climate-friendly, and, in line with the promotion of renewable energy, to reach the climate targets of the Paris Agreement. Currently, the direct electrification of vehicles comes with challenges. Even though significant advancements in battery and charging technology and infrastructure have been achieved in recent years, a key concern regarding battery electric propulsion is the time needed to recharge electric batteries and the relative limitation of range of travel for vehicles using this technology, compared to those using internal combustion engines (ICEs). In addition, worries about battery depreciation and high costs often hinder customers from switching from ICEs to battery electric vehicles. Battery swapping[2] promises to solve those issues by, as a complement to conventional charging, allowing the change of battery packs from one that is empty to one that is charged, within minutes.

In addition to battery swapping technology, Battery-as-a-Service (BaaS) is offering innovative business models linked to the energy sector. BaaS is typically defined as a service model enabling people to buy an electric car without buying its battery pack. Instead, customers can sign up for energy plans where they pay monthly rental fees for battery use, and are able to choose from battery packs of different capacities.

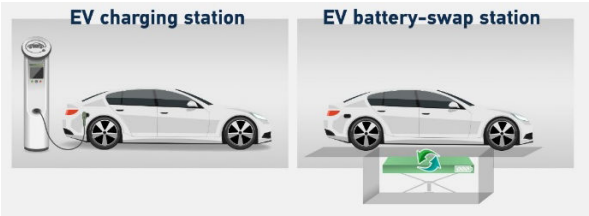

Figure 1: EV charging and battery swapping, Source: Yin Yating, CGTN

1 Including battery electric, hybrid, plug-in hybrid, fuel cell electric vehicles, solar cell vehicles, supercapacitor vehicles, and internal hydrogen combustion engine vehicles.
2 In battery swapping stations, robots physically remove empty batteries from vehicles and replace them with fully charged batteries.

History of battery swapping

The idea of swapping batteries and BaaS is not entirely new. Battery swapping was first proposed well over a century ago, in 1896 and put into practice between 1910 and 1924 by the Hartford Electric Light Company, a subsidiary of General Electric. Customers could purchase vehicles without a battery from the General Vehicle Company (GeVeCo) and the power could be purchased from Hartford Electric as a swappable battery. The vehicle owner paid a flexible per-mile charge as well as a monthly service fee for maintenance. In 1917, a similar service was operated for owners of Milburn Light electric cars in Chicago.[3] In the 1970s, Mercedes tested battery swapping and built about 40 electric buses with a manual horizontal battery swapping system (see figure 2) but concluded that the technology was not safe. Due to these quality concerns, the project was not continued.[4]

Figure 2: Battery swapping on an electric Mercedes bus in the 1970s, Source: The Green Optimistic

More recently, the concept of battery swapping was introduced by the company Better Place in 2008, which at its peak operated 21 battery swapping stations in Israel (see figure 3) and expanded its services in cities around the world.[5] Despite its initial success, the company filed bankruptcy in May 2013, mainly due to financial issues and the fact that the NEV market was far from being ready to be rolled out on such a scale, and demand for the service was low.

3 https://en.wikipedia.org/wiki/Range_anxiety
4 https://www.greenoptimistic.com/mercedes-versus-project-better-place-20090311/
5 The company in 2011 also announced a cooperation agreement with the China Southern Power Grid Company and signed a Memorandum of Understanding with Chery Automobile to develop prototypes for electric vehicles to be used in regional state-sponsored pilot projects.

Figure 3: Better Place Charging Station, Source: Wikipedia

In 2013, Tesla demonstrated battery swapping as a potential complement to fast charging with the ability to change the battery of a Tesla Model S within 90 seconds. Tesla then constructed a battery swapping station at Harris Ranch between Los Angeles and San Francisco, offering the service at a price of around EUR 50. However, even though Tesla's battery swapping system was considered to be a technological breakthrough, the company's plans to deploy battery swapping stations were abandoned in 2015, due to a lack of customer interest. Discussing the cancellation of the plans, Tesla's CEO Elon Musk said of the idea: „clearly, it's not very popular", then focused on the expansion of Tesla's supercharger network.

In the context of other vehicles however, battery swapping became popular in the field of scooter and kick-scooter sharing when companies such as Gogoro or Voi used the technology to solve the range problem faced by these modes of transport, therefore increasing levels of customer acceptance. Battery swapping was also widely introduced in warehouses for the operation of electric forklifts and is now increasingly discussed as a partial solution to the electrification of long-haul heavy-duty freight transport. Besides battery swapping technology systems, Battery-as-a-Service (BaaS) business models are becoming increasingly popular, as they offer opportunities – particularly for car manufacturers – to get into the energy business itself, which is associated with an overall transformation in the field of transport towards electric mobility.

In summary, both battery swapping and related energy business and service models are not new inventions, but they have never been successfully adopted on a large scale. As China's battery swapping and BaaS are now being actively promoted by the government and pushed forward by companies such as NIO, Geely, CATL or Aulton New Energy Automotive Technology, this context could drastically change.

Battery swapping and BaaS in China

China is the world's largest vehicle market, and the country considers electro-mobility as an important key to its industrial transformation and energy security, particularly in regards to the to promotion of clean transport and the achievement of the 2030 carbon dioxide peaking and 2060 carbon neutrality targets set by Chinese president Xi Jinping in 2020. With approximately 7.84 million NEVs already on the road in China[6] (2021), which accounts for about half of the global NEV population, and a total of 75,000 charging stations and 2.62 million electric vehicle charging piles[7] (2021), China is the world's largest electric vehicle market, reaching a domestic NEV market penetration of 14.8%.[8] In 2021, NEV sales in China reached 3.52 million units, an increase of 160% compared to 2020.[9] According to the New Energy Vehicle Industry Development Plan (2021-2035), by 2025, the country aims to have electric vehicle sales comprise approximately 20% of total new car sales (they stand currently as comprising 5% of the total)[10] and by 2035, the majority of new vehicles sold should be pure electric vehicles.

6 http://www.caam.org.cn/chn/7/cate_120/con_5235354.html
7 http://www.news.cn/english/20220121/5bda964b2f3e4669b-558087b927c009b/c.html
8 http://www.xinhuanet.com/english/2021-06/19/c_1310016120.htm
9 https://news.cgtn.com/news/2022-01-12/China-s-NEV-sales-rank-first-globally-for-7th-year-16LdGlpOUUM/index.html
10 https://transition-china.org/mobilityposts/china-issues-the-blue-print-for-its-electric-vehicle-and-intelligent-connected-vehicle-indus-try-development-for-the-next-15-years/

With an increasing share of battery electric vehicles on the road, a more diversified landscape of charging options is emerging, to better meet the different demands of customers. Battery swapping is also being promoted as a charging option, both by the Chinese government and also companies, including NIO, Geely, the Beijing Electric Vehicle Co Ltd and CATL. By the end of 2021, 1,298 battery swapping stations were in operation in China[11] with the majority of stations being operated by NIO and Aulton New Energy Automotive Technology. While still being in its infancy, many experts predict the market for battery swapping infrastructure and related energy business models to significantly increase over the next few years. According to Mr. Zhang Feng, Deputy General Manager of Blue Park Smart Energy (Beijing) Technology, "In the next 5-10 years, the number of commercial vehicles with potential demand for battery swapping will reach 4 million", and furthermore, "we believe that by 2025, the number of battery swapping NEVs will reach 1.24 million, with 12,370 battery-swap stations needed".[12]

Battery swapping in China is currently being promoted by the government mainly in the form of guiding policy support, subsidies, pilot programs and standardization efforts.

Policy support

The Chinese government has introduced various policies to guide and support the development of the battery swapping industry since 2019. In June 2019, the National Development and Reform Commission (NDRC), the Ministry of Ecology and Environment (MEE) and the Ministry of Commerce (MOFCOM) jointly issued the Implementation Plan for Promoting the Renewal and Upgrading of Key Consumer Products and Smooth Resource Recycling (2019-2020)[13], which proposes to encourage enterprises to develop NEV products with a combination of charging and swapping options, and flexible battery configurations.

The New Energy Vehicle Industry Development Plan (2021-2035), which was published by the State Council Office of the People's Republic of China on 02 November 2020, has clear deadlines for the implementation of battery swapping systems. Specifically, the plan notes that battery swapping will be encouraged, the construction of battery swapping infrastructure will be accelerated, the modular traction battery standard system will be established and improved, by 2025 overall battery swapping services will be significantly improved, and by 2035, the overall battery swapping service network will be convenient and efficient. The plan functions as a top-level policy, guiding investment, research and development (R&D), the formulation of subsequent policies and promotion programs, and the implementation of pilot projects.

In its New Infrastructure Plan, which was announced at the 2020 National People's Congress by the CCP, China targets the active promotion of, and investment of about EUR 1.15 trillion into, "new infrastructure" (新型基础设施) as a top-level development priority.[14] In line with Made in China 2025[15] and the China Standards 2035 Plan, "new infrastructure" refers to "digital, smart, and innovative" infrastructure including 5G networks, industrial internet, inter-city transportation and rail system, data centers, Artificial Intelligence (AI), ultra-high voltage power transmission, and new-energy vehicle charging stations.

In the Report on the Work of the Government, which was delivered at the fourth session of

11 http://www.news.cn/english/20220121/5bda964b2f3e4669b-558087b927c009b/c.html
12 https://epaper.chinadaily.com.cn/a/202101/04/WS5f-f2575aa31099a234352f90.html
13 http://www.gov.cn/xinwen/2019-06/07/content_5398219.htm

14 https://www.china-briefing.com/news/how-foreign-technolo-gy-investors-benefit-from-chinas-new-infrastructure-plan/
15 Made in China 2025 refers to the Made in China (MIC) 2025 document, which was released in 2015 by the Ministry of Industry and Information Technology (MIIT) and outlines how China shall shift from being a low-end manufacturer to becoming a high-end pro-ducer of goods by transitioning the country's existing manufacturing infrastructure and labor market towards producing more specialized outputs, including for the target sector of energy saving and new energy vehicles (Source: China Briefing)

the 13th National People's Congress of the People's Republic of China on 05 March 2021, it was stated that in 2021, "more parking and electric vehicle battery charging and swapping facilities will be built" (in 2021).[16]

Subsidies

Multi-level fiscal support measures, in particular the granting of national level vehicle purchase subsidies and the exemption of NEVs from the 10% vehicle purchase tax, are key to the successful uptake of electro mobility in China. During the Executive Meeting of the State Council on 31 March 2020, it was determined that the NEV purchase subsidy policy, which before was set to expire on 31 December 2020, would be extended for another two years until the end of 2022. Additionally, it was decided that the pre-subsidy selling price of new energy passenger vehicles must be below 300,000 RMB (approximately 38,600 Euros). However, In order to encourage the development of battery swapping technology and in view of its current high cost, battery swapping vehicles would not be subject to this price capping requirement.[17]

Standardisation

On 06 May 2021, China's State Administration for Market Regulation (SAMR) approved the National Standard for Battery Swap Safety Requirements for Electric Vehicles (GB/T 40032-2021). This standard is the first mandatory standard governing the development of battery swapping in the EV industry in China, and is considered to be significantly important as the current lack of uniformity in standards is a key obstacle to the development of EV battery swapping systems in China. The standard was drafted by companies including NIO, Beijing Electric Vehicle Co Ltd, and GEELY and came into effect on 01 November 2021 specifying safety requirements, test methods, and inspection rules for battery swappable electric vehicles (for example, vehicle models with snap-on batteries need to be able to support at least 5,000 battery swaps, while models with bolt-on batteries need to be able to support at least 1,500 battery swaps).[18]

On March 18, 2022, the Ministry of Industry and Information Technology (MIIT) released the "Highlights of Automotive Standardization Work in 2022". The MIIT proposed to speed up the construction of electric vehicle charging and battery swapping standard systems, and promote the development of standards for these systems, common platforms and battery packs for EV battery swapping.

Title	Status
Interchangeability of onboard battery swap system of pure electric commercial vehicle Section 5: Communication of vehicle and battery pack	Submitted for approval
Interchangeability of onboard battery swap system of pure electric commercial vehicle Section 4: Swappable battery pack	Submitted for approval
Interchangeability of onboard battery swap system of pure electric commercial vehicle Section 3: Battery swap mechanism	Submitted for approval
Interchangeability of onboard battery swap system of pure electric commercial vehicle Section 2: Battery swap cooling connector	Submitted for approval
Interchangeability of onboard battery swap system of pure electric commercial vehicle Section 1: Battery swap electrical connector	Submitted for approval
Common platform for battery swap of pure electric passenger car Section 4: Communication of battery pack and facility	Submitted for approval

16 http://www.xinhuanet.com/english/download/2021-3-12/report2021.pdf

17 More information can be found here: https://transition-china.org/mobilityposts/recent-changes-to-new-energy-vehicle-nev-incentive-policies-in-china/

18 https://cnevpost.com/2021/05/10/battery-swap-national-standard-to-go-into-effect-nov-1/

Common platform for battery swap of pure electric passenger car Section 3: Battery Pack	Submitted for approval
Common platform for battery swap of pure electric passenger car Section 2: Vehicle	Submitted for approval
Common platform for battery swap of pure electric passenger car Section 1: Communication of vehicle and facility	Submitted for approval
Interchangeability of onboard battery swap system of pure electric passenger vehicle Section 5: Communication of vehicle and battery pack	Submitted for approval
Interchangeability of onboard battery swap system of pure electric passenger vehicle Section 4: Swappable battery pack	Submitted for approval
Interchangeability of onboard battery swap system of pure electric passenger vehicle Section 3: Battery swap mechanism	Submitted for approval
Interchangeability of onboard battery swap system of pure electric passenger vehicle Section 2: Battery swap cooling connector	Submitted for approval
Interchangeability of onboard battery swap system of pure electric passenger vehicle Section 1: Battery swap electrical connector	Submitted for approval

Figure 4: Current Project Proposals for Standardisation of Battery Swap Technologies, source: National Committee of Auto Standardization

Pilot project promotion

China's Ministry of Industry and Information Technology (MIIT) and the National Energy Administration (NEA) decided to jointly organize a nationwide pilot programme for the application of battery swapping, with the aim of promoting the innovative application of battery swapping technology, an in-depth integration of NEVs within the energy sector, and supporting the achievement of the 2030 carbon dioxide emission peaking and 2060 carbon neutral targets.[19] The programme consists of seven major components, including taking action on key technology R&D, rolling out the target of promoting battery swapping vehicle pilot projects in public sectors such as public transport, car rentals, urban logistics and distribution, and ports and mines, and promoting commercial operations in the private sector. Based on the actual demands of cities, reasonable and feasible goals for the promotion of battery swapping will be set to encourage the first pilot projects in these areas. The first eleven cities to be included in the pilot programme are Beijing, Nanjing, Wuhan, Sanya, Chongqing, Changchun, Hefei, Jinan, Yibin, Tangshan and Baotou, with the latter three focusing on truck applications. The pilot project aims to build more than 1,000 battery swapping stations and put more than 100,000 additional battery swap EVs on the road. According to the proposals from the pilot cities, the battery swap network is expected to help save more than 700,000 tonnes of fuel per year, and remarkably, more than two million tonnes of CO_2 per year.[20]

19 https://new.qq.com/omn/20210427/20210427A0EGD300.html
20 http://www.gov.cn/xinwen/2021-10/28/5647458/files/bf3ff9f87e294d699da92d6109003b60.pdf

Overview on selected companies related to battery swapping and BaaS in China

Over recent years, various Chinese companies have been developing and expanding battery swapping infrastructure networks and respective BaaS models. Strategic partnerships have been formed between automakers, shared mobility service and taxi companies, battery swapping service companies and energy companies, with the aims of bundling resources and knowledge and sharing costs.

Vehicle manufacturers

• **Aiways:** In 2021, Aiways formed a strategic partnership with Blue Park Smart Energy, engaging in battery swapping businesses, aiming to jointly develop battery swapping technologies and battery swappable electric vehicles, cooperate on the production and sale of facilities related to battery swapping stations and big data, as well as brand promotion, so as to meet the energy supply demands for taxis and ride-hailing services. In the coming years, these companies plan to co-deploy at least 20,000 electric vehicles

Figure 5: Selection of companies engaged in battery swapping and BaaS, Source: GIZ

With the guidance of government policies, it is expected that more such partnerships will emerge in the coming years. Figure 5 demonstrates a selection of companies who are actively engaging in battery swapping, BaaS and mobile internet-based power solutions as part of their larger electro mobility and energy ecosystems in China.

equipped with swappable battery packs across 17 cities, and build over 200 battery swapping stations to form a network for scale battery swapping services.[21]

• **BAIC Beijing Electric Vehicle Co Ltd (BJEV):** BJEV operates 225 battery-swap stations in 19 cities in China. In 2018, BJEV was already selling its EV300 compact car for approximately EUR 9,900 including an all-you-can-swap battery deal for approximately EUR 50 a month.[22] As of November 2020, the company had 22,000

21 http://autonews.gasgoo.com/new_energy/70018180.html
22 https://electrek.co/2020/01/17/ev-battery-swapping-is-dead-in-us-but-china-wants-to-make-it-happen/

battery swapping vehicles on the road.[23] By the end of 2020, the company also had 142 taxi battery swapping stations operating in Beijing.[24]

• **Changan Automobile Co.:** Changan Automobile launched its first battery swap station in Chongqing along with a consortium including CATL, Aulton New Energy Vehicle Technology Co., and State Grid, and now plans to expand their services to Hangzhou, Jinan and Zibo.

• **Dongfeng Motor Corporation Passenger Vehicle Company (DFPV):** Dongfeng Motors and Aulton recently formed a strategic partnership for battery swapping, aiming to jointly develop the Dongfeng Fengshen E70 electric vehicle equipped with swappable batteries, which will be rolled out in Wuhan and Nanjing for ride-hailing services.[25]

• **Geely:** Geely launched its first battery swapping station, known as E-Energee, in Chongqing in September 2020[26], and now has established 39 battery swapping stations in China, with plans to expand to 200 locations by 2023 and then eventually, up to 1,000 locations through established agreement.[27] According to Mr. Yang Quankai, head of battery swapping at Geely, by 2025, the company will have 5,000 battery-swap stations in operation across China[28]. Unlike the swapping stations of other companies, Geely's stations are front entry / rear exit with car plates being identified on entry, and the respective fees are automatically charged to the driver's account. The average swap costs approximately EUR 7, which will fully replenish a car's full range capacity (around 400km under NEDC's ranges).[29] Geely's battery swapping stations have a capacity of 39 batteries, serving up to 1,000 vehicles per day. Geely also has developed its first battery swapping vehicle, the Maple 80V and in November 2021 unveiled its first electric truck (the Homtruck), which will also be able to swap batteries. The company aims to deliver the trucks by 2024, and to produce 570,000 Homtrucks by 2030. To build a battery swapping ecosystem, Geely in 2021, set up a joint venture (JV) with Chongqing Ruilan Automotive Technology Co., together with Lifan Technology. Under the JV, Ruilan (which is holding a 50% capital share in the EUR 83 million JV) is to build up their network of battery exchange stations (totalling 5,000 stations by 2025, covering more than 100 core cities). The stations should be based on the Global Battery Rapid Change (GBRC) platform, indicating plans to later expand the system globally.[30]

• **NIO:** NIO offers BaaS subscription-based swappable batteries for customers, functioning as complement to conventional charging options. The BaaS service allows the company to sell vehicles without a battery. Customers can save EUR 8,900 when purchasing the vehicle with a 70kWh battery (see Figure 6) and can sign up for different battery sizes (70kWh or 100 kWh with an upgrade from 70kWh to 100kWh being priced at EUR 7,400 or EUR 64 per month with the BaaS subscription) and so-called 'power plans'. Currently, a 70kWh pack is priced at approximately EUR 120 per month. NIO built its first battery swapping station in 2018, and currently operates 828 battery swapping stations in China. Of these 828 stations, 220 are located on highways.[31, 32] In 2019, the company announced the completion of its first network of battery exchange stations, built along the G2 motorway between Beijing and Shanghai, with eight stations spaced out over a length of more than 1,000 kilometers.[33]

23 https://epaper.chinadaily.com.cn/a/202101/04/WS5ff2575aa-31099a234352f90.html
24 http://www.bj.xinhuanet.com/2020-12/11/c_1126849442.htm
25 http://autonews.gasgoo.com/m/70018137.html
26 https://www.scmp.com/business/china-business/article/3164575/volvo-owner-geely-automobile-forms-partnership-develop
27 https://paultan.org/2021/06/18/geely-to-stick-to-integrated-battery-tech-for-evs-based-on-sea-platform-battery-swapping-still-a-long-way-off/
28 https://www.sohu.com/a/440920654_99902275
29 https://www.dsf.my/2021/05/advantages-of-geely-battery-swapping-tech/
30 https://www.electrive.com/2022/01/25/geely-lifan-launch-battery-swapping-jv/
31 http://www.chinadaily.com.cn/a/202105/17/WS60a1b-90ca31024ad0babe2bb.html
32 https://www.electrive.com/2022/01/29/nio-marks-800-battery-swapping-stations-in-china/
33 https://www.electrive.com/2019/01/20/nio-completes-first-battery-swapping-route/

By the end of 2022, NIO aims to operate a battery swapping station network of more than 1,300 stations in China, and by 2025, the company aims to operate 4,000 battery-swap stations globally, of which 3,000 are planned to be in China.[34, 35] To date the company has already completed a total of approximately 5.3 million battery swaps in China.[36] NIO's second-generation battery swapping stations have a capacity of 13 batteries, enabling 312 battery swaps per day. NIO, in early 2021, signed an agreement with Sinopec, for strategic cooperation on battery swapping stations and has constructed a battery swapping station at Sinopec's Chaoying gas filling station in Beijing. On August 18 2021, the EUR 101 million Weineng Wuhan Battery Asset Co., Ltd. joint venture, initiated by NIO, CATL, Hubei Science Technology Investment Group Co., Ltd. and Guotai Junan International Holdings Limited, was registered and established as a battery asset company, which will purchase battery packs and commission NIO to provide battery subscription and operation services to users[37]. As the owner of battery assets, the battery asset company plays an important role in BaaS. As part of its internationalization strategy, NIO recently opened the first battery swapping outlet in Norway, and is expected to launch services in Germany in the course of 2022 (NIO already received TÜV certifications to sell and operate its battery exchange stations and chargers in all EU member states).[38, 39]

- **SAIC Motor Corp.:** The SAIC Motor Corp. is cooperating with Aulton New Energy Automotive Technology to start operation of the first battery swap station for its EVs.

Vehicle Model	ES 8		ES 6		EC 6	
Price for vehicle (RMB)						
Battery Capacity	75 kWh	100 kWh	75 kWh	100 kWh	75 kWh	100 kWh
Basic Price	476,000	534,000	358,000	416,000	368,000	426,000
Purchase Subsidy for NEV	11,340	12,600	11,340	12,600	11,340	12,600
Basic Price incl. Purchase Subsidy	464,660	521,400	346,660	403,400	356,660	413,400
Price Reduction for BaaS	70,000	128,000	70,000	128,000	70,000	128,000
Basic Price incl. Purchase Subsidy and BaaS	394,660	393,400	276,660	275,400	286,660	285,400
Price for Battery Rental (RMB)						
Monthly Rent Price	980	1,480	980	1,480	980	1,480
Monthly Service Fee	80	80	80	80	80	80

Figure 6: NIO vehicle purchase prices, Source: GIZ based on NIO data (04/2022)

34 https://www.electrive.com/2022/01/29/nio-marks-800-battery-swapping-stations-in-china/
35 https://electrek.co/2021/07/09/nio-plan-open-battery-swap-stations-to-other-electric-automakers/
36 https://www.electronicdesign.com/markets/automotive/article/21216583/electronic-design-batteryswapping-stations-pick-up-the-pace-in-china
37 https://www.nio.com/news/nio-launches-battery-service
38 https://www.electrive.com/2022/01/29/nio-marks-800-battery-swapping-stations-in-china/
39 https://www.electrive.com/2021/07/09/nio-receives-certification-for-battery-swapping-stations/

Battery swapping station operators and service providers

• **Aulton New Energy Automotive Technology:** As of May 2021, Shanghai-based battery swapping station operator Aulton has operationalized 316 battery swapping stations in more than 20 cities across China including Beijing, Shanghai, Chongqing, Guangzhou and Kunming (see Figure 7). In 2022, Aulton aimed at operating 500 new battery-swap stations, covering more than 50 cities, with the total number of stations to reach 800. By 2025, the company aims to build at least 10,000 battery-swapping stations in 100 cities in China, serving more than 10 million NEVs.[40] Aulton's battery swapping technology is currently compatible with nine models of vehicles, from seven mainstream automakers.[41] Aulton has formed partnerships with approximately 14 automakers, including Changan Auto, the BAIC Group, SAIC Motor, the FAW Group, the GAC Group, and Dongfeng Motor, and has co-developed 22 battery swappable electric vehicle models with these partners. The company has a strategic partnership with Changan EV, which has handed over 100 battery swappable Eado EV460s to the Chongqing Taxi Operation Association, who use Aulton's battery swapping stations in Chongqing.[42] Aulton also signed a strategic cooperation framework agreement with Sinopec aiming at combining their technologies and expertise to explore areas of commercial application for intelligent charging, and carry out practical cooperation on the research and application of battery charging and swapping.[43] On 20 July 2021, Aulton operationalized two battery swapping stations in Shanghai and Chongqing, which were built in partnership with Sinopec.[44] At the end of 2021, BP acquired a stake in Aulton, aiming to use the joint venture to offer battery swapping services for taxis, ride-hailing vehicles and other passenger cars, initially in the Chinese city of Guangzhou.[45]

Figure 7: Aulton battery swapping station in Shanghai, Source: China News Service

• **Blue Park Smart Energy (Beijing) Technology:** By 2025, Blue Park Smart Energy (Beijing) Technology, a battery service subsidiary of BAIC, aims to build 2,500 battery swapping stations covering at least 120 cities in China.[46] In January 2021, SK Innovation announced that it rose to become a major strategic investor by acquiring 13.3% of shares (see Figure 8).

Figure 8: Blue ParkSmart Energy (Beijing) Technology battery swapping station in Hangzhou, Source: SK Innovation

• **China Tower Corporation Limited:** The telecommunications tower infrastructure service provider, under its energy business, operates about 24,000 battery exchange depots (not battery swapping stations, as operated by other companies listed in this paper) in more than 100 cities across China providing power battery exchange services to low-speed electric vehicles of courier and logistics companies including Meituan, Ele. me, Fengniao, China Post, SF Express, JD.com, STO, YTO, ZTO, Best Express and Yunda.[47]

40 https://www.electrive.com/2021/11/23/bp-backs-battery-swapping-in-china-with-aulton/
41 https://www.chinadaily.com.cn/a/202101/25/WS600e29bba31024ad0baa4ce8.html
42 http://autonews.gasgoo.com/m/70018368.html
43 https://pandaily.com/sinopec-and-nio-jointly-build-power-swap-station-at-beijing-chaoying-filling-station/
44 https://cnevpost-com.cdn.ampproject.org/c/s/cnevpost.com/2021/07/21/aultons-first-battery-swap-stations-with-sinopec-go-into-operation/amp/
45 https://www.electrive.com/2021/11/23/bp-backs-battery-swapping-in-china-with-aulton/
46 https://epaper.chinadaily.com.cn/a/202101/04/WS5ff2575aa31099a234352f90.html
47 https://www.bloomberg.com/news/newsletters/2021-04-06/hyperdrive-daily-battery-swapping-makes-a-comeback-in-china

Energy and battery companies

• **Contemporary Amperex Technology (CATL):** In 2019, CATL, together with Hellobike and Ant Financial, held a strategic cooperation conference in Shanghai at which they announced the establishment of a joint venture with a total investment of EUR 127 million, involving the initiation of battery swapping services for two-wheeled electric vehicles[48]. On August 18 2021, Weineng Wuhan Battery Asset Co., Ltd., initiated by NIO, CATL, Hubei Science Technology Investment Group Co., Ltd. and Guotai Junan International Holdings Limited, was registered and established as a battery asset company, which will purchase battery packs and commission NIO to provide battery subscriptions and operation services to users.[49] In January 2022, CATL's subsidiary CAES (Contemporary Amperex Energy Service Technology Ltd.) unveiled its own so-called EVOGO battery swapping system, which includes: 1. Battery fast swapping stations; 2. „Choco" modular Swappable Electric Blocks (SEB)s, and; 3. Their own service APP. EVOGO enables users to rent and change EV batteries (Choco-SEBs) in CAES's own fast battery-swap stations. Every EVOGO battery swapping station is the size of 3 standard parking lots, and houses 48 Choco-SEB batteries, with a swapping time for each Choco-SEB of 1 minute (see Figure 9). Each Choco-SEB can achieve a weight energy density of more than 160Wh/kg and a volume energy density of more than 325 Wh/L and each 26.5-kwh Choco-SEB can enable a driving range of about 200 km. Users can choose to load 1 or 3 Choco-SEBs depending on their needed capacity and range and could potentially lease one block with the vehicle, and then rent additional blocks as needed for longer trips. According to CAES, the EVOGO service will be accessible for all automakers and will work for 80% of all currently available EVs, as long as they are built on a dedicated EV platform. CAES has already introduced the battery swapping version of FAW Group's Bestune NAT multipurpose vehicle, which was the first member of the EVOGO family. The EVOGO battery swapping standard adheres to existing battery swapping standards; OEMs have to develop Choco-SEB compatible battery swapping brackets for them to be used. The EVOGO system will be launched in 10 cities in China (though a timeline for this plan is not yet available).[50] As a leading company in battery production, CATL's implementation of battery swapping services is expected to have a huge impact on battery standardization for battery swapping, driving the participation of other companies and boosting consumer confidence in the overall battery swapping service industry.

Figure 9: EVOGO battery swapping station, Source: EVsmartBlog

• **China Petrochemical Corp (Sinopec):** Sinopec, in partnership with NIO, launched a battery swapping station in Beijing in April 2021, and plans to construct 5,000 additional battery swapping stations across China over the next few years (see Figure 10). The company recently signed a strategic cooperation framework agreement with Aulton and the Evergrande Group, which includes plans for the joint construction of charging and battery swapping facilities. On 20 July 2021, Aulton has put into operation two battery swapping stations in Shanghai and Chongqing, which were both built in partnership with Sinopec.[51]

48 https://www.catl.com/en/othercase/523.html
49 https://www.nio.com/news/nio-launches-battery-service

50 https://www.catl.com/en/news/856.html
51 https://cnevpost-com.cdn.ampproject.org/c/s/cnevpost.com/2021/07/21/aultons-first-battery-swap-stations-with-sinopec-go-into-operation/amp/

Figure 10: NIO battery swapping station launched at Sinopec fuel station in Beijing, Source: China Daily

• **State Grid EV Service:** As a subsidiary of State Grid, the State Grid EV Service has signed strategic cooperation agreements with BAIC, FAW, Dongfeng, NIO and other OEMs, actively exploring the application of the „vehicle-electricity separation" business model, and jointly building and operating battery swapping stations.

Transport and Mobility Companies

• **Chongqing Taxi Operation Association:** The association operates battery swappable Eado EV460s by Changan EV as taxis, using Aulton's battery swapping stations in Chongqing (see Figure 11).

Figure 11: Opening ceremony- Changan EV Eado EV460s as battery swappable taxi in Chongqing, Source: Aulton

• **Hellobike:** On 12 June 2019, Hellobike held a strategic cooperation conference with CATL and Ant Financial Services Group in Shanghai, establishing a joint venture with an initial investment of 1 billion yuan, aiming to launch a battery-swap service to develop a basic energy network of two-wheeled electric vehicles. The three parties will work to integrate their superior resources and capabilities of industry, operation, and travel mobility to comprehensively build a travel ecosystem to provide green, intelligent, and safe battery-swap services for two-wheeled electric vehicle users[52].

52 http://finance.sina.com.cn/roll/2019-06-12/doc-ihvhiews8410749.shtml

Summary

There are many arguments for and against battery swapping as part of the wider electro mobility technology, service and business model ecosystems. This document serves to provide an overview of the progress in this field, to date, in China, with the hope to present some insights on both the drivers and barriers faced by the related industries. In conclusion, a list is presented here of the key aspects to consider when assessing the opportunities and challenges of battery swapping and BaaS.

Potentials of battery swapping and BaaS

1. Reduced vehicle purchasing costs due to the separation of vehicle body and battery (as the battery – one of the most expensive parts of the vehicle – is sharable);

2. With subscription-based BaaS models, customers do not own their own battery and therefore do not need to worry about battery depreciation, range declines and battery disposal, potentially increasing the acceptance of electro mobility transport options and decreasing respective concerns;

3. Increased acceptance of second-hand electric vehicle purchases, as the battery is not part of the vehicle;

4. Increased convenience for travel and fleet operation, as it does not take a significantly longer amount to time to swap a battery than it does to fill a tank with fuel. In particular, for long distance trips and commercial vehicles with long operating hours (including taxis), ride-hailing fleets and logistics vehicles, swapping is a much faster option than traditional charging methods;

5. Cost benefits for shared logistics, mobility, and delivery companies with large fleets, as BaaS battery leasing models covers the costs for service, repair, and the replacement cost of batteries;

6. New service and energy business models related to BaaS (e. g. subscription-based monthly power plans) are an attractive and available for car manufacturers and battery operation companies to get into the energy business associated with vehicle electrification;

7. Extended battery life and safety with the battery operation company centrally in charge of the monitoring, maintaining and managing of batteries;

8. Reduced charging costs with charging available at preferential rates during off-peak hours, potentially leading to lower energy costs for customers;

9. Energy and cost saving for consumers, who can choose to rent a battery with the capacity they need for the day, based on their daily mileage and travel plans (depending on costs of specific energy/ power plans);

10. Improved battery end of life (EoL) management and better management of battery recycling as the onus of recycling batteries lies with the battery swapping operator – this will prevent consumer problems with battery disposal;

11. Potential for grid integration with battery swapping stations as grid-balancing energy storage devices, and;

12. Potential optimised land resource allocation compared to separate charging pile construction – for example necessary infrastructure like swapping stations could be integrated into existing municipal structures.

Challenges of battery swapping and BaaS

13. Complexity due to a lack of uniformity in standards across the industry, with batteries of different car manufacturers and models having different chemistries, power and energy densities, and form factors, and different drivetrains requiring different energy and power ratios. Furthermore, car manufacturers have been reluctant to share their battery and battery management systems standards;

14. Battery swapping stations are expensive to develop as stand-alone structures (estimated costs for one are EUR 350,000 to 1.3 million) including costs for land, labor, maintenance, electricity and the stored batteries, and therefore can require a significant upfront investment;

15. Battery inventory management, planning and operation can be complex, particularly with ensuring the availability of sufficiently charged batteries in swapping stations with different levels of flow. Planning needs to ensure the right numbers are available at the right time in low-, medium-, and high-density urban areas, rural areas, and along highways;

16. Technical issues need to be dealt with, to prevent rainwater, snow or dust entering the vehicle's electric system or affecting battery stores during swaps, and;

17. Improvements in the efficiency and capacity of battery and charging technologies, with solid-state batteries promising potential ranges of more than 1,000 km per charge, may mean that battery swapping could become an outdated technology in the near future.

Conclusion

Battery swapping must not be seen as a replacement of conventional charging methods, but rather as a complementary technology diversifying the choices of electric vehicle users. Choices currently available range from conventional charging methods, on demand mobile charging, battery swapping, and the option to flexibly upgrade batteries to meet customer's specific and individual demands. Battery swapping and BaaS technologies can be of benefit to personal vehicle owners, but can also be of particular use to operators of commercial and shared vehicle fleets, such as ride-hailing, taxi and urban delivery fleets by increasing the operation time of their vehicles. In addition, battery swapping might be an effective component in the roadmap to electrifying long-distance heavy-duty freight transport services. In addition, BaaS solutions where customers do not own their batteries, but instead sign up for flexible energy plans, open new opportunities and business models for vehicle manufacturers and energy companies, potentially further accelerating the trend of vehicle electrification.

In the future, it can be expected that battery and charging technology will continue to advance, leading to increased capacities and ranges, shortened charging times and lower costs. The role that the application of battery swapping and BaaS will play in the transport industry the long run has therefore yet to be determined. For now, battery swapping and BaaS continue to demonstrate the potential to reduce customer's concerns over limited ranges of use, long charging times and high battery costs that often influence levels of anxiety in customers on switching from ICEs to battery electric vehicles. The availability of battery swapping and Baas options at the moment therefore can support an increase in the uptake of, and acceptance for, battery electric mobility transport options.

To fully tap the potentials of battery swapping and BaaS, the overall costs for related infrastructure construction, operation and maintenance need to be significantly lowered and utilization rates of battery swapping stations must be increased. These steps can be achieved by the provision of sufficient governmental support both in terms of fiscal and non-fiscal support measures, in-depth cross industry/sector and manufacturer cooperation and partnerships, overall coordinated infrastructure and energy system planning, and further automation and technological development. Most importantly, to eliminate the existing complex diversity of types and standards within battery swapping and Baas materials and infrastructure, standards need to be in place to ensure cross manufacturer and model compatibility. In the future, a flexibility in battery pack layouts aiming to eliminate massive battery packs and the promotion of flexible configurations could also be explored. Finally, the possible resource and environmental impacts of battery swapping should be carefully assessed when planning the deployment of battery swapping technology and systems.

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Sitz der Gesellschaft
Bonn und Eschborn

Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Deutschland
T +49 228 44 60-0
F +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Deutschland
T +49 61 96 79-0
F +49 61 96 79-11 15

E info@giz.de
I www.giz.de