Insight paper

Battery-as-a-Service: an underexplored opportunity?

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SHOOSMITHS

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About Shoosmiths

Shoosmiths LLP is a law firm operating from 13 locations across England, Scotland and Northern Ireland and a recently opened office in Brussels. Clients are offered strength and depth in all the core legal disciplines, together with deep specialism and sector expertise. A key tenet of the firm's strategy is its focus on five sectors – Mobility, Energy & Infrastructure, Technology, Living, and Financial Services.

Electric vehicle (EV) charging infrastructure impacts on all those sectors and, as such, is an area of combined focus for the firm's sector groups.

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- advising on numerous chargepoint installation and operation agreements with a range of charging equipment suppliers for landowners, developers, retailers, and automotive manufacturers.
- advising on the investment fund formation and deployment strategy for a major fund bidding to manage the UK Government's Charging Infrastructure Investment Fund.

Clients can depend upon Shoosmiths' collaborative legal teams to bring together a mix of real sector insights, innovative styles of advice, and enviable technology to deliver exceptional service.

Acknowledgements

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About Cornwall Insight

Getting to grips with the intricacies embedded in energy and water markets can be a daunting task. There is a wealth of information online to help you keep up to date with the latest developments but finding what you are looking for and understanding the impact for your business can be tough. That's where Cornwall Insight comes in, providing independent and objective expertise. You can ensure your business stays ahead of the game by taking advantage of our:

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Foreword

At the back end of 2020, the government published a plan to put an end to the sale of new petrol and diesel cars in the UK by the end of the decade. While welcome news for many, this target – the most ambitious in the G7 – brought into sharp focus the practical challenges associated with achieving such a goal. One of the biggest challenges facing both the government and industry is meeting the need for an extensive electric vehicle (EV) charging infrastructure to support the predicted increase in the number of EVs on the road.

Year-to-date figures released in May 2022 highlighted that EV registrations in the UK are exploding – up 171% on the year-to-date figure for May 2021[1]. By the end of 2022, EV sales are forecast to outstrip their diesel and hybrid counterparts. In contrast, the ratio of EV charge points to plug-in cars deteriorated by 31% during 2020 alone[2].

A report published in March 2022 puts Britain's current ratio of charge points to plug-in EVs at 16:1; behind other countries including South Korea (3:1), the Netherlands (5:1), France (10:1), Belgium, and Japan (both 13:1). It is estimated that the number of chargepoints will need to increase tenfold by 2030 to cater for the anticipated numbers of EV drivers. At present, there is an uneven geographical distribution of EV chargepoints across the UK and rollout is significantly behind what is needed to meet the anticipated demand in the 2030s.

The government's recently announced UK Electric Vehicle Infrastructure Strategy is a step in the right direction in regard to addressing on-street chargepoint demand, but it is not a silver bullet for EV infrastructure[3]. In urban centres, where dwellings largely comprise flats with no access to off-street parking, there will be a higher demand for on-street chargepoints and other, more flexible solutions. Meanwhile, in rural areas where long or regular commutes are less common, slower home chargepoints may prove a more economical solution.

This raises several questions:

1. What learnings can we take from how other countries are approaching EV infrastructure?
2. Are there alternative solutions to complement the existing, planned EV chargepoint infrastructure?
3. Could Battery-as-a-Service (BaaS) be one such solution?

BaaS is a subscription-based model of battery ownership, allowing EV users to swap out a depleted battery for a fully charged one at a service station. So far, BaaS is in an embryonic stage of development and, just like conventional EV charging infrastructure, it is not without its own challenges. However, early signs are that it is working successfully in China with the principal market incumbent, NIO, now looking to roll it out in Europe.

To enable battery swapping as a scalable solution, there would need to be a relatively high level of industry standardisation in design, size, and vehicle compatibility. It follows that the development of BaaS in a meaningful way would require a supportive regulatory environment in which companies across the mobility sector could collaborate. Just as it plans to do with attracting research and development (R&D) investment in autonomous vehicle technology, the UK Government would need to (a) provide a supporting regulatory framework, (b) consider tax-related R&D incentives, and (c) encourage collaboration between relevant industry stakeholders to make it work. However, given the issues identified in this report with conventional EV chargepoints and capacity – or a lack thereof – BaaS definitely merits further consideration as, at least, a complementary part of a wider EV infrastructure solution.

Shoosmiths has commissioned this report to consider the merits and challenges of BaaS and whether it is a viable option for the UK; whether to supplement 'traditional' charging infrastructure, or to help meet demand in specific conurbations. I hope you enjoy reading it, and that points raised sparks conversation.

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[1] SMMT

[2] Connected Kerb

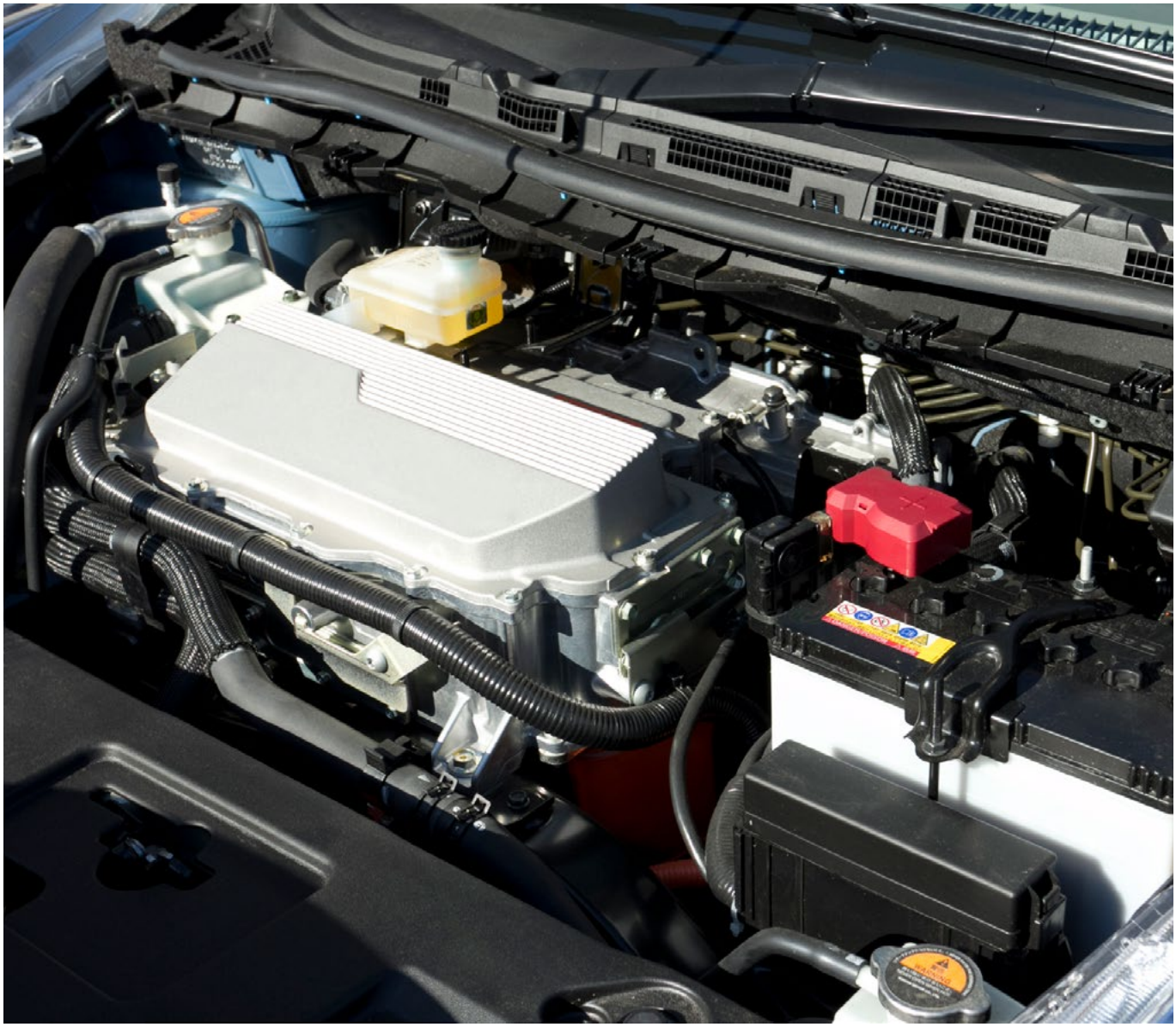
[3] UK electric vehicle infrastructure strategy | GOV.UK

Executive summary

Battery-as-a-Service (BaaS) is an electric vehicle (EV) ownership model which, at its core, seeks to divorce the costly battery component from the vehicle. Instead, BaaS provides an EV infrastructure solution whereby users subscribe in exchange for the ability to swap a depleted battery for a fully charged one at a swapping station.

The principal benefits of this approach are twofold. Firstly, it introduces a level of convenience and speed that EV users have not previously enjoyed through traditional charging methods. This ultimately means less time off the road. Secondly, it means that the upfront cost of each EV is significantly reduced as the integrated battery is the single most expensive component of many EVs.

Though it may sound novel, the underlying concept of BaaS has been around for some time. A similar model, where consumers leased the battery as a separate lease to the vehicle itself, was first introduced in 2007. Ultimately, the idea did not gain traction at the time, arguably because of the lack of maturity in the EV market. However, with the recent boom in EV uptake and ownership, owed in large part to disruptors like Tesla, a refined BaaS model is now being rolled out and is attracting consumer engagement, particularly in China.



What is the potential for BaaS?

When we consider just a handful of the key challenges impacting EV uptake – particularly in the UK – the BaaS model is well placed to provide a potential solution. These key issues, and BaaS's solutions include:

- Reducing issues around range anxiety, given the ability to swap a depleted battery for a fully charged battery in a matter of minutes.
- Reducing the upfront cost of an EV, and granting greater consumer flexibility, through the battery subscription approach.
- Offering a solution for inner city charging where homes do not have access to at-home plug-in chargepoints.

In addition to these consumer benefits, the BaaS model presents further advantages across the mobility value chain, including:

- Offering flexibility for the electricity network, by allowing unutilised batteries to be discharged onto the electricity network at swap stations during peak hours.
- Offering battery recycling and reuse opportunities, such as using second-life swappable batteries in an onsite storage facility at swap stations.

Despite the opportunities presented by the BaaS model, there are many challenges that need to be overcome to make it a viable and successful model in the UK. These include:

- Overcoming limitations owing to a lack of battery standardisation across EV manufacturers. Without a significant level of battery standardisation, battery swap stations cannot be scalable, and each swap station would only service a specific make or model of car. It is unlikely that any one manufacturer would have the appetite, or the capital investment required to develop, deliver, and service the technology and infrastructure required.
- A potential lack of relevance as the overall declining upfront cost of EVs reduces the savings benefit presented by the BaaS model.
- Continued access to supplies of the raw materials required to manufacture batteries. The UK does not have extensive indigenous supplies of the necessary raw materials and battery production is therefore at risk from unstable geo-political relations with the raw mineral source countries.
- Consumer choice lock-in for other EV charging models, which may weaken market entry for BaaS.
- Uncertainty over the ownership of the battery, particularly when the BaaS EV is re-sold, and consumer confidence and engagement with the BaaS model.

Despite these challenges, the BaaS model could work with the right investment and business collaboration. It could be a viable option for specific areas, such as EV fleet cars (e.g., taxis or car rental companies). A business-to-business BaaS proposition would have a slightly different set of economics and would not need widespread battery swapping infrastructure as they tend to operate in specific areas or specific routes with a controlled density of vehicles.

The BaaS model provides an alternative to EV chargepoints and more work needs to be done by central government and local authorities to fully quantify the advantages and challenges of the BaaS model and its role alongside EV chargepoints, rather than rushing ahead with largescale EV charging infrastructure rollout as the sole 'solution' to EV charging. If the BaaS model were to take off, particularly in the UK, partnerships between the government, technology companies, distributors, car manufacturers, and original equipment manufacturers would be key. Specifically, support from government could help to boost investment into BaaS; a more supportive regulatory framework including enhanced R&D incentives. A more encouraging environment for collaboration between relevant industry stakeholders is also critical at this stage.

The resurgence of BaaS

1

The resurgence of BaaS

1.1. What is Battery-as-a-Service?

In the Battery-as-a-Service (BaaS) model, electric vehicle (EV) owners purchase the EV without the battery, reducing the upfront cost of the EV. The battery is then provided in the form of a subscription or lease agreement. Typically, this might take the form of a monthly subscription, whereby alongside the ability for 'traditional charging', the depleted battery can be swapped at specialist automated stations for a fully charged battery in a matter of minutes. The empty battery is placed into a charging port, where it is fully charged and can then be swapped into another vehicle.

BaaS is not a new concept. Better Place, a venture-capital backed Israeli start-up company – founded in 2007 and based in California – has previously developed and sold battery swapping services for EV cars to address the concerns of consumers around a lack of charging infrastructure, known as range anxiety, and to defer the cost premium of EVs caused by the high cost of the batteries. The uptake for its battery swapping solution was limited and it found only one EV manufacturer partner (Renault) as other manufacturers were concerned about being tied into using a standardised battery pack. There was only one EV model, the Renault Fluence Z.E. that was able to use the battery swap system. Better Place built infrastructure in many locations, including in Israel, Denmark, Japan, and California, at a cost of $2mn for each battery swapping station before filing for bankruptcy in November 2013. Notwithstanding Better Place's failure to launch, the concept proved to be ahead of its time and may well have been hampered by limited market demand for EVs in the early 2000s. The large investment needed to develop the charging and swapping infrastructure also meant that users had to drive long distances to swap their batteries, which limited customer satisfaction. Recognising the potential of the idea, Tesla trialled battery swapping with Model S owners in California in 2013 when the EV market was still nascent but seemingly ceased the service after two years. The lack of consumer interest relative to the increasing popularity of the company's growing supercharging network was suggested as one of the driving factors for discontinuing the service.

Despite the previous challenges faced by the BaaS model, there is promise for the technology in the near future. Given the proportion of EVs in the market is now much greater than a decade ago, and backing from governments for EVs has increased, BaaS may have the potential to fill gaps not met by other EV charging models and may offer a useful alternative to on-street charging. As discussed later in this paper, Chinese EV manufacturer NIO has successfully rolled out BaaS infrastructure in China and is now looking to roll it out in Europe.

> "BaaS may have the potential to fill gaps not met by other EV charging models and may offer a useful alternative to on-street charging."

1.2. Why do we need BaaS?

1.2.1. The UK context

With the government banning the sale of new petrol and diesel cars in the UK by 2030, as part of its target to reach net zero by 2050, the EV market is expected to grow from 0.5mn in 2021 to 14mn by 2030[4]. The proportion of drivers who said they plan to purchase a fully EV as their next vehicle has grown from 2% in 2017 to 14% in 2021[5] and by May 2022 14% of new cars registered were EVs[6]. By 2050, EVs are expected to need 65-100TWh of electricity each year, an increase of 20-30% on current levels[7].

There are many obstacles to overcome in order to see the widespread adoption of EVs. Principal among these are issues surrounding cost and range anxiety, as well as concerns about a lack of charging infrastructure. Range anxiety is likely to be resolved in the short term, with some new model EVs able to cover 300 miles plus. However, the shortage of chargepoints continues to be an issue. In March 2022, the Department for Business, Energy & Industrial Strategy (BEIS) published its EV Infrastructure Strategy, which recognised that the current chargepoint roll out is too slow, public charging costs are opaque and unreliable, and that more local planning is needed to ensure the current rollout is even across the country[8]. The Society of Motor Manufacturers and Traders (SMMT) has indicated that the continuation of the transition will depend on the preservation of incentives that overcome the affordability barrier and the ability of the public and private sectors to increase public on-street charging to allay EV driver concerns[9].

Regarding the issue of costs, an OC&C Strategy Consultants survey[10] found that 69% of UK consumers actively considering an EV did not want to spend more than £500 extra on the difference between an internal combustion engine (ICE) vehicle and an EV. Felicity Latcham, Associate Partner at OC&C, said the actual price differential seen between most equivalent ICE and EV models tends to be substantially upwards of £500, meaning that in many cases consumers are deterred by the cost of EVs.

Costs have been further exacerbated by increases in battery pack prices. While prices for these materials have been set to decline year-on-year[11], current rising commodity prices and raw material supply risks due to geo-political tensions have meant that there is increased pressure on the battery production industry. This has resulted in uncertainty about future costs for producing battery packs with prices likely to remain higher than expected in the coming years.

In the case of infrastructure, increased EV demand necessitates the roll out of over 300,000 new chargepoints across the UK[12], together with the requirement for a new and upgraded electricity supply network. The government's EV Infrastructure Strategy highlighted that a minimum of 300,000 public chargepoints will be required in the UK by 2030, a very large increase on the current 29,600 chargepoints in place[13]. A survey by OC&C Strategy Consultants in 2019 found that 64% of consumers were concerned about finding enough places to charge their car when they were out. This dropped to 50% in 2021 as infrastructure started to catch up, but more needs to be done to alleviate concerns.

1.2.2. A role for BaaS

BaaS could be a solution to concerns around the lack of EV charging infrastructure, EV range and the high battery cost. The battery pack is the single most expensive part of an EV and accounts for around 30% of the cost to consumers. By leasing or subscribing for a swappable battery, the upfront cost of an EV is significantly reduced. Professor Rohit Bhagat, Centre Director and Chair of Electrochemical Energy Storage at the Centre for E-Mobility and Clean Growth Research (CEMR) at Coventry University, noted that the "better use that is taken from the battery pack, the cheaper the cost of ownership will be". In addition, the BaaS model centralises and speeds up charging processes, as well as overcoming issues related to limited potential for home plug-in chargepoints in areas such as inner cities.

An example of this is the BaaS offering provided by Chinese EV manufacturer NIO, where a depleted battery can be swapped out in less than five minutes for a fully charged battery providing up to 380 miles of range[14]. This contrasts to standard EV charging, where a Tesla Supercharger takes 15 minutes to provide 200 miles of range[15]. NIO customers can also subscribe to a range of battery pack capacities to suit their travel needs.

> "A minimum of 300,000 public chargepoints will be required in the UK by 2030, a very large increase on the current 29,600 chargepoints in place."

[4] Enabling the transition to electric vehicles | Ofgem
[5] Aviva
[6] SMMT
[7] CCC
[8] UK electric vehicle infrastructure strategy | GOV.UK
[9] SMMT
[10] OC&C 2021 Automotive Speedometer
[11] EVO Report 2021 | BloombergNEF | Bloomberg Finance LP (bnef.com)
[12] CCC
[13] UK electric vehicle infrastructure strategy | GOV.UK
[14] NIO
[15] Tesla

1.3. BaaS around the globe

1.3.1. China

At present, the largest market for BaaS is in China. The Chinese Government has supported the battery swapping technology industry and the 2020 policy of national new energy vehicle (NEV) subsidies has recognised the vehicle-battery separation based on battery swapping technology. The Chinese Government regards power swap stations as part of the overall answer to EV infrastructure. In July 2020, China's Vice Minister of Industry and Information Technology Xin Guobin announced that the government will 'vigorously' pursue the construction of EV charging infrastructure and battery swapping and encouraged companies to develop and test vehicles with replaceable batteries.

> NIO owners can swap their depleted battery at battery swap stations in three to five minutes with the fully charged battery providing them with a 380-mile range."

NIO

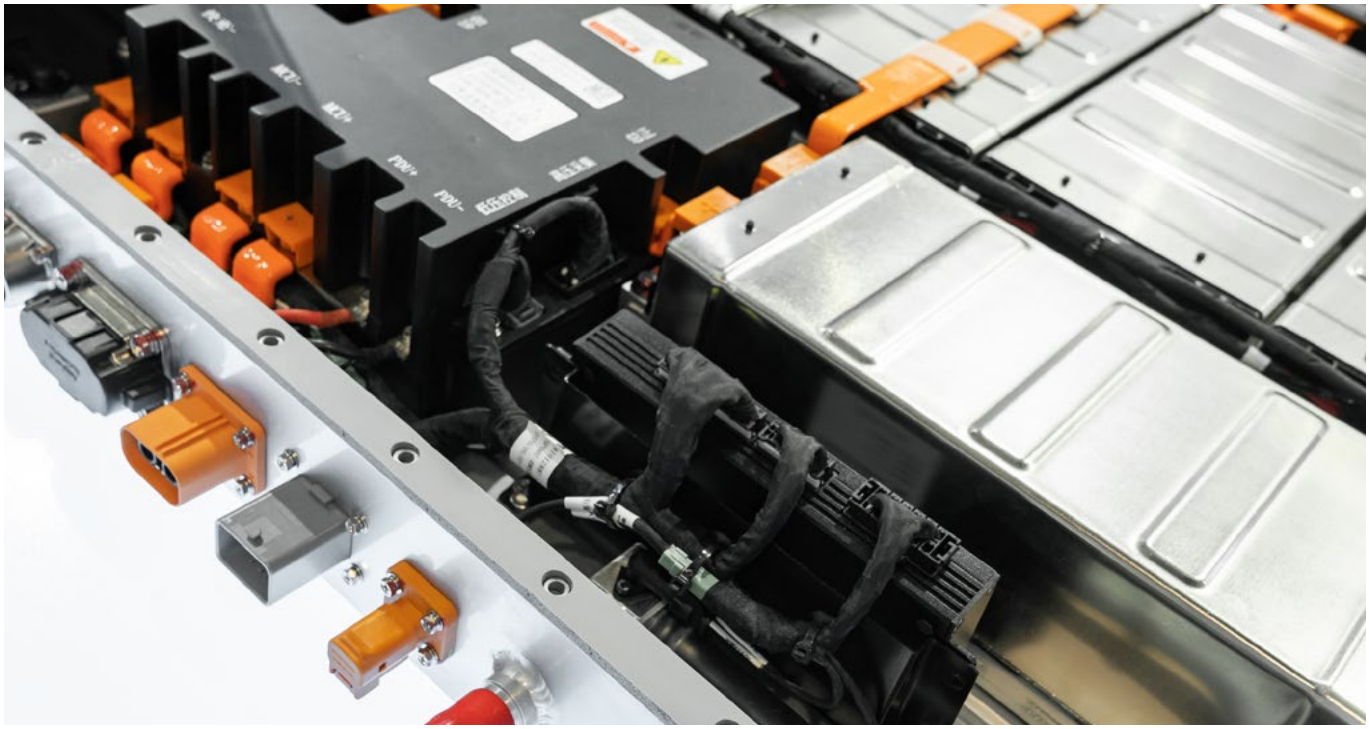
Chinese EV manufacturer, NIO, officially launched its BaaS offering in August 2020. It believes that its BaaS offering represents a 'systematic solution' to EV battery degradation, battery upgradability, and lower resale value.

1. EV users can purchase a NIO EV without the battery and subscribe to NIO's BaaS subscription service, which provides battery packs of varying capacity, according to needs, with customers paying on a monthly basis. The service includes the NIO Power Swap and flexible battery upgrade services. Customers that purchase NIO cars with BaaS pay the equivalent of around £8.3k less on all models, with subscription to a 70kWh battery pack costing around £116/month for up to six swaps[16]. As at January 2022[17] the company had installed 800 battery swap stations in China and provided over 5.3mn battery swaps. It noted that in November 2021, 42% of NIO users lived within 3km of a swap station with each swap station serving around 258 cars[18]. The company has also installed 645 destination charging stations across China, which offers users an alternative charging method.
2. According to the company, NIO owners can swap their depleted battery at battery swap stations in three to five minutes with the fully charged battery providing them with a 380-mile range. The batteries take around one hour to recharge in the swapping station and each station can complete 312 battery swaps per day[19]. In comparison, the Tesla Supercharger allows users to top up their car to 200 miles in 15 minutes[20]. The price per mile of range is also marginally cheaper for the NIO BaaS model (8.3p/mile) compared to the equivalent price for a Tesla Supercharger (8.6p/mile)[21].
3. With NIO's BaaS customers able to subscribe to battery packs of various capacity according to their needs, it makes the service viable for a wide range of EV users, both those who primarily do short inner-city journeys and those who do longer journeys. The ability to switch the subscription to a different battery type provides flexibility to the users.
4. NIO BaaS users also have access to NIO charging stations, of which it has over 3,000 power chargers and over 3,300 destination chargers, and NIO also has roaming agreements giving customers access to over 430,000 third party chargers[22], so they are not restricted to swapping their battery each time it runs low. Its 7kW and 20kW home chargers provide further charging capabilities with charging times of 14 hours and five hours respectively for a 100kWh battery.

Battery asset company, Weineng Wuhan Battery Asset Co. Ltd was created by NIO alongside Contemporary Amperex Technology Co. Limited (CATL), Hubei Science Technology Investment Group Co. Ltd. and a subsidiary of Guotai Junan International Holdings Limited. The battery asset company purchases the battery packs and commissions NIO to provide the battery subscription and operation services to users.

Where NIO's service offering differs to its predecessors is that it is making BaaS and battery swapping standard across the entirety of its model range. Tesla made the service available for only one of its models, and similarly, Better Place worked with only one model by one manufacturer.

[16] NIO
[17] NIO
[18] NIO
[19] NIO
[20] Tesla
[21] Data Driven Investor
[22] NIO



Other providers

NIO is leading the way for BaaS in China; however, other companies are also entering the space:

- In May 2020, CF Energy[23], an energy service provider in China, announced that EDF CF – a joint venture between CF Energy and EDF (China) Holdings Ltd – had signed an exclusive co-operating agreement with BAIC Qingxiang Technology Co., Ltd (BAIC QX)[24] and Blue Valley Smart (Beijing) Energy Technology Co., Ltd to provide EV battery swap services in the Hainan Province. BAIC QX released 200 swap-battery EVs for Network Taxis in Sanya City and committed to a further 200 more in the months following the announcement.
- Chinese car manufacturer Geely has said it aims to install 5,000 battery swapping stations for EVs in China by 2025 through its associated service, E-Energee[25]. Its first battery swapping station was installed in September 2020 and it has since expanded to 10 Chinese provinces. The service is primarily for EV fleets.

While battery swapping works well in China, other countries have different policies, infrastructure and environments, which means the success of BaaS will not necessarily be easily replicated elsewhere.

[23]CF Energy Corp.

[24]A subsidiary of BAIC Motor Corporation., Ltd which is one of the largest EV producers in China.

[25]Geely

1.3.2. United States

In the United States, start-up company Ample launched in March 2021, raising $230mn to embark upon modular battery swapping, initially for commercial vehicles with the potential to move to passenger cars and SUVs. Its ambition is to get car manufacturers to make versions of their EVs that have an adapter plate instead of a full battery pack into which Ample will plug battery modules. The modules can then be swapped at automated battery swap stations regardless of vehicle size or model. These vehicles will be sold to fleets that want to go electric. It highlights the selling points for this approach as reduced charging time, a swap station rather than several high-capacity chargers, and less on-site infrastructure.

1.3.3. India

In India, SUN Mobility, a joint venture between Maini Group and SUN Group, announced in August 2021 that it aims to tackle the unique challenges faced by India's urban transportation through its Mobility-as-a-Service (MaaS) model for multiple vehicle platforms, including two and three-wheelers and buses with an unlimited swap plan for the duration of the contract[26]. SUN Mobility has 65 swap points across 14 cities in India and aims to have over 500 swap points by the end of 2022.

The Mahindra Group signed a partnership with Jio-BP – a joint venture between BP of UK and Reliance Industries – in December 2021 to explore the creation of EV products and services including business models like MaaS and BaaS. It says the partnership aims to accelerate EV adoption in India with high performance and swappable batteries that will help dispel range anxiety.

1.3.4. South Korea

Hyundai signed a memorandum of understanding (MoU) with South Korea's Ministry of Trade, Industry and Energy, together with Hyundai Glovis, LG Energy Solution and KST Mobility, for the rental of electric taxi batteries and the sustainable reuse of EV batteries in energy storage systems (ESS). KST Mobility, a taxi operator, will sell the ownership of batteries in newly purchased EVs to Hyundai Glovis, the battery lessor. KST Mobility will then pay a monthly fee for battery usage which means it will have a lower initial investment on EV purchases. After extensive usage, the batteries will be reused in ESS for fast-charging EV taxis. ESS will be charged at off-peak times when electricity rates are lowest and EV taxis will be charged during the daytime when electricity is comparatively expensive. Hyundai will oversee all the business operations and will be responsible for providing battery warranty and replacement batteries for vehicles that return batteries after use.

1.3.5. Europe

Norway has achieved the highest European EV penetration so far, with the number of EVs increasing substantially over the last decade from 1,200 battery EVs in 2008 to approximately 290,000 in 2019, accounting for around 9% of total cars. Incentives have been in place for many years to make the cost of EVs cheaper than conventional petrol and diesel vehicles.

NIO launched its ES8 model in Norway in September 2021, marking the start of its service offering there, including its BaaS model. The first charging and swapping station in Norway was built and ready at the end of October 2021. NIO plans to build 20 power swap stations in the country by the end of 2022, covering its five largest cities and their main roads. Each swap station has 14 battery slots and 13 battery packs, with an empty slot to pick up a discharged battery.

NIO also plans to introduce its products and 'holistic service system' to Germany, the Netherlands, Sweden, and Denmark in 2022[27]. It aims for 1,000 swap stations to be built outside China by the end of 2025 and to establish a presence in over 25 countries and regions worldwide by 2025.

Aside from NIO's entrance into Norway and expected entrance to other European countries, from 2022 drivers of the XEV YOYO[28] city car in Italy and Germany will have access to a battery swapping service, Battery Xchange, at selected Eni service stations following an agreement between XEV and Eni[29].

1.3.6. UK

BaaS is not a charging model that currently exists in the UK. However, this model could help to resolve issues around the cost of batteries, patchy public charging infrastructure and limited vehicle range, which have been highlighted by the government in publications such as Decarbonising UK Transport report[30] and the UK Electric Vehicle Infrastructure Strategy[31]. The official government position continues to be that the commercial case for battery swapping is yet to be proven[32] and the technology has not been a particular focus in strategies and reports related to EV markets.

Alternative charging methods are being developed such as that by ZipCharge[33], see box below.

ZipCharge 'Go'

ZipCharge has developed a portable 'smart' charger on wheels, similar in size to a 'compact' suitcase. This device can be charged from any plug socket and wheeled to an EV where it can charge the EV using a standard type 2 cable via the charge port. It provides 20-40 miles of range in 30 to 60 minutes dependent upon the capacity and vehicle. The charger costs 'the same as a fully installed home charger'.

[26] SUN Mobility
[27] NIO
[28] XEV Global
[29] ENI
[30] Decarbonising UK transport: technology roadmaps | GOV.UK
[31] UK electric vehicle infrastructure strategy | GOV.UK
[32] Common misconceptions about electric vehicles | GOV.UK
[33] Zip Charge Global

1.4. Engagement with BaaS models

1.4.1. Customer engagement

With an ever-increasing number of EVs on the road and the phasing out of ICE vehicles, market conditions are now more conducive for the success of the BaaS model.

At present, NIO provides its BaaS offering to all users, individual consumers and fleet customers. Other companies that have entered the BaaS market, such as Geely, BAIC and Ample, have focused on offering the service solely to fleet customers. Taxi fleets are currently the primary route to market for most companies entering the BaaS space.

A key factor in customer engagement with BaaS is the shift in mindset towards subscription models. This is a phenomenon that has been observed in all sectors, not just the mobility space. The consumer shift in subscription mindset has been seen in everything from software-as-a-service, telecoms (e.g., SIM-only deals), ride-hailing (e.g., Uber, Lyft, and Bolt), car sharing (e.g., Zipcar and Hiyacar), and the consumption of media (e.g., Netflix and Amazon Prime). The key to the success of these models is the flexibility they afford the customer, without much upfront commitment or cost and the revenue certainty provided to the company offering the service.

However, Jonathan Carrier, co-founder of ZipCharge, highlighted that for a consumer to make the shift to an EV requires "a huge amount of behaviour change" and people resist because of lack of belief in it, lack of trust, or they find it too confusing. With BaaS, there is an added level of uncertainty for consumers around what happens when the vehicle is sold and where the ownership lies which means there is a "huge level of cognitive dissonance" between the reality of what is on offer and what the consumer understands. Carrier added that the early EV adopter community were willing to take a risk and to try something new, but this is not the same for the mass market, where consumers want the experience of owning and driving an EV to be simple.

1.4.2. Business-to-business engagement

With regard to the business-to-business (B2B) aspect of the BaaS model, there is also a shift in mindset around collaboration among various participants within the automotive ecosystem. Historically, partnerships on projects and technology sharing within the automotive industry have been limited, but now there is more recognition around the benefits of corporate collaboration to achieve success and longevity. As will be discussed later, NIO, for instance, partnered with Shell in 2021 for its roll out plan, which has helped towards meeting its 2021 end goal of building 700 swapping stations.

> “A key factor in customer engagement with BaaS is the shift in mindset towards subscription models.”

Opportunities to capture value in the BaaS model

2

Opportunities to capture value in the BaaS model

2.1. Benefits for the end-customer

The increasing use of battery storage technology over the last two years, particularly in China, has highlighted the many benefits of the BaaS business model for consumers. Principal among these are the reduction in range anxiety and the reduction in the upfront costs of an EV. Batteries are the single most expensive component of a new EV, accounting for up to 30% of the EV's total on-the-road cost. By removing this from the vehicle, the upfront purchase cost is significantly reduced. The cost of the battery is, in essence, then spread out in more manageable payments across the battery subscription period. Battery swapping can provide customers with a quicker alternative to conventional EV charging as well as a longer range. A NIO user can swap to a fully charged battery with a 380-mile range in three to five minute.

BaaS models service a particular need in inner cities where access to on-street and off-street parking are likely to be more limited; this is especially the case in areas with a high density of flats or apartments. Similarly, consumers in rented homes are unlikely to be permitted to install a home chargepoint by their landlord and so BaaS offers a solution to these individuals. This is a particular advantage in the UK and mainland Europe, where the home rental market is significant.

BaaS providers offer the subscriber the opportunity to vary their subscription package – and therefore the amount they pay – to meet their needs in any given month. For example, by having a lower capacity battery for a month in which they anticipate only commuting short distances to and from work, whilst upgrading to a longer-range battery when they might have a significant journey planned.

Frequent rapid charging of batteries can increase the rate of degradation of the EV battery and therefore potentially result in higher battery costs due to shorter battery life. Battery swapping may prolong battery life and lower the overall battery cost, despite the need for multiple batteries at charging stations. The International Energy Agency (IEA) noted that although the use of swappable batteries increases the number of total batteries needed to support a fleet, it can significantly reduce operational emissions and enable a longer lifespan of vehicles.[34] Similarly, battery swapping has been found[35] to have a higher energy efficiency than plug-in battery charging, hydrogen, or catenaries[36] due to the lower energy losses and longer battery life from slow battery charging. Together with the electrification of transport, predicted lower cost and environmental impacts, the IEA found it to be an attractive way forward compared to other forms of battery charging.

To achieve the benefits of battery swapping and for full and fast deployment, a much wider and international effort is required. This needs to include involvement from automotive manufacturers and battery producers, robotic and electrical device industries, electrical grid operators, national authorities, fuel service station owners and, importantly, engagement from consumers.

Alongside the benefits to consumers that are key to the attraction of the BaaS model, there are additional opportunities to extract value from EV batteries. These opportunities range from the reuse and recycling potential to their inclusion in network flexibility programmes.

> A NIO user can swap to a fully charged battery with a 380-mile range in three to five minutes."

[34] Global EV Outlook 2021 | IEA

[35] Why we need battery swapping technology, A.M. Vallera, P.M. Nunes, M.C. Brito, October 2021

[36] Overhead wire system used to supply electricity to locomotives such as a tram or light railway.

2.2. Second-life battery storage

EV batteries have around a 10-year lifespan before needing to be replaced due to a material loss of charging capacity and the accompanying reduction in range. It is projected that by 2030 there could be around 13mn tonnes of EV batteries available for reuse and, by 2035, global requirements for stationary energy storage could be met by second-life batteries.[37] Research has found that extending the life of a battery in a repurposed application has the potential to cut its embedded emissions by 50%.[38] Around 70-80% of the battery's original capacity is maintained in the 'end-of-life' batteries and they are therefore a valuable resource for energy storage systems. Jonathan Smart, Partner and Head of Mobility at Shoosmiths highlighted the importance of developing second-life activities and this is only likely to grow as batteries become a key source of power and more research and development is carried out.

By replacing the most degraded cells in an 'old' EV battery, the battery can be reused in another application outside of a vehicle for up to an additional 12 years based on calculations from the sustainability campaign group and industry platform, RePurpose. Research has found that a properly managed system of used EV batteries could be a 'good profitable investment' as long as the batteries cost less than 60% of their original price. For it to be successful it would need a number of stakeholders to be involved, including the EV manufacturer, the lithium-ion battery manufacturer and the project developer.[39] Second-life EV batteries used in energy storage systems that are integrated into photovoltaic and wind power plants can last up to an additional 10 years in these less demanding roles.

Recycling and utilising a product and its components with a sustainability focus is on most major developers' agendas now, according to Shoosmiths' Jonathan Smart. Polestar (the Geely/ Volvo joint venture), for example, recently announced that they were looking to make the world's first truly carbon neutral vehicle whereby the entire production is sustainable. There are also many examples where end-of-life EV batteries have been used for energy storage systems.

However, one of the main barriers to attracting more capital into the second-life battery industry is safety. Retrofitting lithium-ion EV batteries for reuse requires extensive testing and upgrades to ensure the reliability of performance in its new application. Investment in the second-life battery industry is more likely to be free flowing if these R&D hurdles can be overcome. One such example of R&D into second-life battery safety is that of RePurpose which is developing a 'non-destructive fire suppression system' that can detect imminent battery failure and prevent the battery from overheating without damaging other electrical components.

Whilst the second-life opportunities for an EV battery are not unique to the BaaS model, by disaggregating the battery from the vehicle it provides an extra supply of batteries, with varying capacities, to be used in second-life applications.

The advantages of re-using 'old' EV batteries are:

- More value is realised from the embedded resource.
- The environmental impact of new battery production and of decommissioning old batteries is displaced.
- Battery recycling is delayed until the processes for it are more efficient and cost effective.
- The batteries' residual value is increased and the economics of transport electrification improved.
- It allows EV manufacturers or battery owners – if the battery is leased – to generate additional revenue.
- It reduces the costs of commercial and grid-scale battery installations.

Some car manufacturers themselves have explored the opportunities for second-life batteries:

- In 2015, Nissan piloted second-life EV batteries in a grid-scale storage installation.
- BMW tested used batteries in demand response events in an 18-month pilot project with Pacific Gas & Electric. Also, in 2015, Daimler AG announced it was to build a 13MW/h second-life battery storage unit at a recycling plant in Germany.
- In June 2017, Powervault and Renault announced a partnership to re-use electric batteries in home energy storage units as part of a trial.
- Retired Nissan LEAF batteries are being used to provide back-up power to Amsterdam Arena under a 10-year agreement. The project went live in June 2018 with the xStorage Buildings System – compromising 148 LEAF batteries – providing 3MW of power and 2.8MW of storage capacity.
- In 2019, Mercedes-Benz Energy worked with Beijing Electric Vehicle to build an energy storage system using retired EV batteries.
- Other manufacturers such as Rivian and Proterra have designed the battery packs in their trucks and electric buses to make end-of-life repurposing as easy as possible from the start.

[37] Greenpeace

[38] Analysis of the climate impact of lithium-ion batteries and how to measure it | Circular Energy Storage

[39] Massachusetts Institute of Technology

2.3. End-of-life recycling opportunities

An assessment by the IEA[40] suggests that to reach the goals of the Paris Agreement on climate change – namely, a global temperature rise below 2°C relative to pre-industrial levels – would mean a quadrupling of mineral requirements for clean energy technologies by 2040, while achieving net zero globally by 2050 would require six times more mineral inputs in 2040 than today. A major contributor to this is the demand for minerals for use in EVs and battery storage, needing to grow at least 30 times by 2040. Lithium is expected to see the fastest growth in demand, with an increase of over 40 times by 2040. However, these demand trajectories are subject to large technological and policy uncertainties.

Recycling would not eliminate the need for continued investment in the supply of virgin materials, but the IEA forecasts that recycling could meet up to 12% of the EV industry's demand for lithium, nickel, copper and cobalt by 2040.[41] It noted that the security benefits of recycling could be much greater for regions where there is wider deployment of clean energy technologies due to greater economies of scale. With the transition to EVs, it is important to ensure that the UK has not only battery manufacturing capabilities, but also recycling capabilities in place to deal with the waste management challenges that end-of-life batteries present. This also creates an opportunity to produce a supply of critical materials for manufacturing new EV batteries. Coventry University's Professor Bhagat highlighted that this is particularly important for the UK, which does not have many indigenous supplies of the materials for EV battery manufacture.

Battery recycling also has the potential to reduce the CO2 impact by making already extracted material available for the production of new batteries, avoiding the processing of new raw materials – an incredibly carbon-intensive process, especially for materials like Lithium. Research has shown that using recycled materials can decrease the energy demand in material production by 48%, providing that the recycling process does not consume more energy than the process of the virgin raw materials it is replacing.[42]

UK-based original equipment manufacturers (OEMs) pay £3-8/kg to recycle end of life lithium-ion batteries that are exported abroad for the extraction of re-usable materials; materials which must then be later repurchased.[43]

As a consequence, vehicle manufacturers themselves are investing in battery recycling, with the Volkswagen Group recycling up to 3,600 batteries a year during a pilot phase at its new plant in Germany[44], while Jaguar Land Rover's venture capital and mobility arm, InMotion Ventures, has invested in Battery Resources, a lithium-ion battery recycling and materials company.[45] End-of-life swappable batteries could provide value to the battery owner involved in the BaaS model, particularly if the recycling and battery manufacture is done 'in-house'. This would save on costs and emissions relating to exporting the battery for recycling and repurchasing the battery materials if it is recycled off-site.

Case study: ReLiB

THE FARADAY INSTITUTION

ReLiB project aims to ensure there are facilities and regulations for the safe, economic and environmentally sound management of materials contained within lithium-ion batteries at the end of their first life to enhance the overall efficiency of the raw materials supply chain. It aims to devise and develop alternative recycling routes that could provide UK businesses with a competitive advantage.

Case study: Technology Minerals

TECHNOLOGY MINERALS PLC

Technology Minerals owns 49% of Recyclus Group Limited, a battery-recycling business. The company focuses on extracting raw materials required for lithium-ion batteries and recycles them for re-use by battery manufacturers. Its first two battery recycling plants were commissioned in February 2022 with one processing plant for lead-acid and one for lithium-ion technologies. It is locating these sites close to market for ease of collection and converting it to black mass.

[40] IEA

[41] The Role of Critical Minerals in Clean Energy Transitions | IEA

[42] Analysis of the climate impact of lithium-ion batteries and how to measure it | Circular Energy Storage

[43] Automotive lithium-ion battery recycling in the UK | The University of Warwick

[44] Volkswagen

[45] Jaguar Landrover

2.4. Network flexibility programmes

Alongside their primary role supporting the BaaS model for EVs, battery swap stations can also be utilised in a range of ways to provide flexibility to the national power grid, and therefore provide additional income for the provision of those services. Any market entrants looking at BaaS should be thinking about network flexibility because "it is the batteries themselves that are a very valuable asset to the grid regardless of whether they get swapped in and out of vehicles," according to an industry source. They also noted that "if there are stations where batteries are being stored and charged, ready for the next customer to take them, then it would be expected that those locations would be doing load balancing according to the grid connection". They further added that the aggregated battery resource should be flexed in order to store energy when it is cheap and available, and then used to alleviate other local constraints or for balancing. This aids the power grid both through providing additional flexibility and reducing the load on the grid at peak times. However, battery swapping demand would need to be prioritised with any network services as secondary.

Bi-directional grid charging

Battery swap stations have the potential to participate in demand side response activities such as bi-directional grid charging. The batteries at the swap station could be charged when electricity is cheap and then act as battery storage for the grid at times of system stress or high demand by providing a proportion of their charge back to the grid while still allowing availability for batteries to be swapped.

Localised flexibility

Local flexibility services are a relatively new market in the UK but one that has seen a lot of growth over the past three years, with the government's Smart Systems and Flexibility Plan[46] suggesting that flexibility could reduce energy system costs by £10bn a year by 2050. Battery swap stations have the potential to provide localised flexibility services to distributed network operators by offering the capability to turn demand up or down. Although, this must be balanced with maintaining sufficient fully charged batteries for EV battery swapping, particularly at times of high swap demand at the station. When choosing the location of battery swapping stations, the load level of the power grid may be a factor which affects where they can be located.

Trading on the balancing mechanism

The balancing mechanism (BM) is used by National Grid to balance electricity supply and demand in real-time. When electricity generation and consumption are out of balance, National Grid can purchase additional generation, or pay to reduce excess generation, to ensure generation and consumption align. In January 2021, the first domestic EV aggregated unit was registered in the BM with a partnership between Flexitricity and ev.energy. Flexitricity said it would use ev.energy's smart EV charging platform of over 10,000 EVs and trade the flexibility from this, using its demand response portfolio of battery storage assets. EV owners set a 'ready by time' to indicate the window in which their EV needs to be charged, Flexitricity's automated platform then interacts with the ev.energy platform to develop and deploy the optimal charging strategy. The flexibility from the EV batteries is then used in the BM and charging occurs when demand is at its lowest and generation is highest, while still allowing the batteries to be fully charged by the set time.

Although there is an opportunity for battery swap stations to operate in the BM, there would need to be management of the sites to know what each site can bid into the BM. According to Joe Camish, Senior Analyst at Cornwall Insight, availability to the BM would be dependent upon demand at the battery swap station and the variable level of charge of the batteries on site at any given time.

Using end-of-life batteries from the BaaS model to create a battery storage asset at the battery swap station is another option where a battery swap station could work flexibly with the grid and the BM. The co-located battery storage asset could be charged at times of low grid demand or when there is plentiful supply on the grid and could also provide the ability to discharge back to the grid without compromising the charge level of fully charged batteries at the swap station. This would also allow for cost avoidance of peak prices.

Frequency response services

National Grid has a licence obligation to control system frequency at 50Hz, plus or minus 1%. Frequency is constantly varying and will fall if demand is greater than generation or will rise if generation is greater than demand. A 2021 study by Zhang et al.[47] found that the operating income of battery swap stations could be increased by participating in frequency response services to maintain system balance. By enabling battery swap station clusters to participate in frequency response, it can make use of idle batteries to increase revenue. It found that under optimised operations, the battery swap income and frequency response income were complementary, so when the battery swap income was high/low, the frequency response income was the opposite. This study was based on battery swap stations in China. However, Joe Camish, Senior Analyst at Cornwall Insight, noted that such battery swap stations could broadly support frequency response services in the UK as well.

[46] Transitioning to a net zero energy system (publishing service.gov.uk)

[47] Operation Strategy for Electric Vehicle Battery Swap Station Cluster Participating in Frequency Regulation Service, Fan Zhang et al., August 2021

Routes to market

3

Routes to market

3.1. Roles for partnerships

Vertical collaboration in the supply chain is almost a necessity to bring BaaS to market, according to Robin Webb, Partner and Automotive Lead at Shoosmiths. It will require end-to-end partnerships between battery manufacturers, original equipment manufacturers (OEMs) and distributors. Among many other considerations, the cost, capital investment, and technological capabilities required to bring BaaS to market at the scale required to make it financially viable is an enormous task for even the largest of companies to face independently. For such a service model to succeed, it will need someone with sufficient capital and infrastructure engagement from manufacturers, as well as concentration of demand, to make it work economically. External investment, technological partnerships and government support and backing will also be key to success.

Partnerships with government

Part of the success thus far for NIO in rolling out battery swapping technology and the BaaS model in China is the support and backing from the Chinese Government. The Chinese Government's 2020 policy of national NEV subsidies, which has recognised the vehicle-battery separation based on battery swapping technology and its recognition of battery swap stations as new types of infrastructure construction, helps to pave the way for BaaS rollout with limited resistance. The government has also actively encouraged companies to develop and test vehicles with replacement batteries.

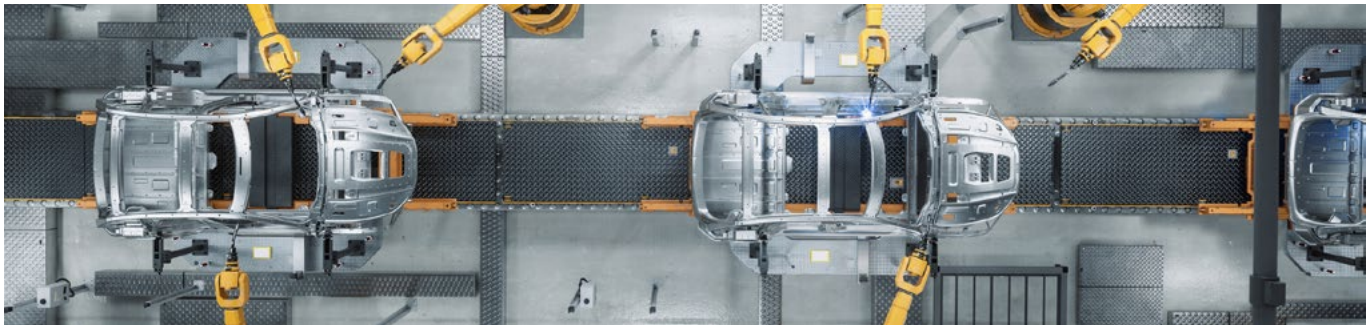
In South Korea, the Ministry of Trade Industry and Energy is a signatory of a MoU between Hyundai, KST Mobility and LG Energy Solutions, creating a partnership between government, an OEM, a taxi operator, a battery lease company, and a company purchasing end-of-life batteries. This partnership provides a battery storage solution for the taxi operator as well as being a global use case for OEMs.

As highlighted in section 1.3.6., there has been little attention from the UK Government on the BaaS model. Clearer engagement from the government, whether through subsidies or direct intervention, would allow the market to take off.

Partnership with fleet companies

Aside from NIO, whose focus is on privately owned EVs, most entrants into the global BaaS arena have been focused on a BaaS business model for fleets, particularly taxi fleets. In South Korea, KST Mobility, a taxi operator, sells the ownership of the batteries in its newly purchased EV fleet to a battery lessor and pays a monthly fee for battery usage. This reduces KST Mobility's initial capital investment in its EV purchases.

One of the advantages of using such nascent battery swapping technology for fleets, particularly taxis, is that they often have a limited range or 'service patch' in which they travel, so the location of battery swap stations would not need to be as widely spread as for privately owned EVs. There would also be more predictability as to the required frequency of battery swaps. With fewer swap stations and a limited number of batteries required compared to a private EV battery swap model there would be less upfront investment needed. This business model also helps taxi companies to go greener, while reducing their outlay on an EV fleet, by removing the cost of the batteries from that initial investment. Battery swapping is also faster than slow, or even rapid, EV charging and would therefore reduce vehicle downtime for fleets.



Partnership with car manufacturers

For the BaaS business model to work, car manufacturers need to be onboard unless, like Chinese car manufacturers NIO and Geely, a car manufacturer is looking to enter the BaaS market themselves by designing and manufacturing EVs with swappable batteries and setting up their own battery swap station network.

Ample's ambition is to get car manufacturers to make versions of their EVs that have an adapter plate instead of a full battery pack, into which Ample can plug battery modules. It is reported to have partnerships with five OEMs, of which nine EV models are to use, or be adapted for, its modular battery packs. Among the EV models which support its battery swapping technology are the Nissan Leaf – the main EV used by Uber drivers – and some KIA EVs.

To make BaaS fully scalable, all car manufacturers would need to be fully involved and enable the EV batteries in their vehicles to be standardised so that battery swapping stations can provide swapping services regardless of the EV make or model. An important variable would be the adoption of a universal battery standard across the industry, much like 5G in mobile phones. This begs the question as to who would reap the benefit of the underlying patent(s). This is not just a question of who has the 'best battery design or technology', but rather a geo-political one. It is hard to see a world in which the G7 member states would be comfortable with the reliance on a Chinese standard for its OEMs, particularly where they form an integral part of the economy, in the case of Germany. This is before we even consider the billions in license fees that would be transferred from the West to China.

Aside from the potential geo-political issues of a standardised battery, some car manufacturers might be reluctant to consider the idea of a standardised battery, as for some, like US car manufacturer Lucid Motors, the design and shape of the battery pack is specifically an aero-dynamic component of the vehicle and a standardised battery would therefore have "huge implications" for vehicle redesign, according to an industry source.

While we are not aware of any OEMs pursuing BaaS in the next couple of years, an industry source noted a shift in thinking towards service and clean energy provisions. For example, Renault announced that it is becoming a tech, service, and clean energy brand.[48]

Partnerships with technology companies

Unless the BaaS market entrant is also a battery manufacturer, they will require the technical expertise of technology companies. NIO, BAIC and Hyundai have all partnered with technology companies to further their battery technology propositions and business models. NIO partnered with Contemporary Amperex Technology Co. Limited (CATL), a lithium-ion battery development and manufacturing company, BAIC partnered with Blue Valley Smart (Beijing) Energy Technology Co., Ltd to provide battery swap station technology, and Hyundai partnered with LG Energy Solution, which develops EV batteries and ESSs.

Collaborating with technology companies providing battery storage systems, and installing these at battery swap stations, takes the BaaS model a step further. It allows for the batteries at a swap station to be charged at off-peak times when the electricity price is lower and then provide the power source for charging the swappable EV batteries which reduces the cost of battery charging. It also offers a second-life use application for end-of-life swappable batteries. The Hyundai MoU uses this business model.

Partnership with distributors

For BaaS to succeed on a widespread scale, a great deal of investment in a battery swapping network will be needed. However, partnerships with distributors, such as NIO partnering with Shell, can open up the swap station network further by allowing swap stations to be built on existing forecourts. NIO's agreement with Shell sees the two companies planning to install 100 battery swapping stations in China by 2025 and start to construct and operate pilot stations in Europe from 2022. Shell's charging network in Europe will also become available to NIO users. These sites will generally be located in prime areas for battery swapping such as at major road networks. Additionally, the partnership between NIO and Shell allows their customers to have access to both companies' EV fast charging networks.

[48] Renault

3.2. Internal capabilities in engaging with BaaS activities

BaaS could be a viable option to explore for companies already working in the EV sector, providing an opportunity to diversify product offerings and income streams in this way. However, this would require "significant R&D investment and capital expenditure" as would "any meaningful roll out of BaaS" says Shoosmiths' Robin Webb. Notably NIO has a large R&D department for developing next generation technologies in connectivity, autonomous driving and artificial intelligence (AI). How feasible it would be for these companies to invest so much into BaaS without government backing and subsidies available from the Chinese Government is questionable. The investment signals provided by the Chinese Government support were crucial in making NIO and Geely R&D investments feasible.

While Tesla had the internal capability to test out BaaS at the start of the 2010s, the market was not ready to receive it. EV uptake was much lower, and at-home chargers were easier to install, with the higher proportion of detached properties in the US compared to China. This meant the demand was not there for the technology at the time.

In the UK context, the recently announced ban on the sale of new petrol and diesel cars from 2030, combined with the global move to net zero has meant that many car manufacturers are focusing on developing their EV range. While some are still in the nascent stages of product development, it could prove a good time to begin engaging and developing swappable battery and BaaS business models. Jacob Briggs, Consultant at Cornwall Insight, believes that the BaaS model could conceptually work in the UK, with investments from other international markets beginning to grow elsewhere, but questions whether there is an appetite for it at present.

> "Most entrants into the global BaaS arena have been focused on a BaaS business model for fleets, particularly taxi fleets."

The way forward

4

The way forward

4.1. Challenges for BaaS

On the surface, the BaaS proposition seems straightforward and addresses many key EV issues such as cost, range anxiety, gaps in charging infrastructure, and charge times. However, there are many challenges that will need to be overcome for it to become more widely adopted.

The level of capital investment required to develop the BaaS technology itself and the swap station infrastructure at the scale required to cater for a mass market is a significant barrier to entry. Andy Turbefield, Head of Quality at Halfords Autocentres, noted that the running costs of battery swapping for the manufacturer are likely to be "huge" and it is only the big Chinese manufacturers that have the resources to do it.

Lack of standardisation in battery models as a barrier to entry

One of the main challenges for delivering the BaaS proposition is the lack of standardised battery products across manufacturers, which means that battery swap stations are only exclusively available to compatible EVs. Even batteries within a single car manufacturer's vehicle range vary in design, and many manufacturers are reluctant to move to a standardised battery across models as this limits the design capacities and capabilities for their EVs. At present, batteries can play a differentiating factor between car manufacturers, and years of R&D investment have gone into the technological developments of such batteries. Without battery standardisation, if a car maker wanted to enter the BaaS market, they would need to install their own network of swap stations. Additionally, with parts manufactured across different countries and EV models available in numerous countries, battery standardisation would need to happen globally. Many car manufacturers are also moving to cell-to-pack or cell-to-chassis where the battery cells are integrated as a structural component of the vehicle to make it lighter and more efficient, which does not lend itself to swappable batteries and standardisation. Halfords' Andy Turbefield suggested the only way battery standardisation can happen is when manufacturers join together to share data and technology, for example Peugeot and Vauxhall. However, several big brands (VW, Tesla, and Ford) are looking to verticalize themselves and bring battery manufacturing in-house. They would therefore not likely be willing participants of battery standardisation. If BaaS were to take off in the UK, it would more likely be the result of a new brand or a disruptor coming into the market with the service offering rather than a big brand already present in the market going down that route, which conjures memories of Tesla at the start of the 2010's. It may well be that NIO already has its sights set on the UK market in its goal to establish presence in over 25 countries and regions worldwide by 2025.

Residual value and battery ownership call into question long-term attractiveness of BaaS

Uncertainty around the ownership of the battery, particularly when it comes to resale of the EV, will impact on the residual value[49]. EVs generally tend to have stronger residual values than ICEs, and these form a large component of the vehicle leasing rate. ZipCharge's Jonathan Carrier noted that "if you destroy the residual values, you will affect the total leasing rate which affects the total cost of ownership", which reduces the attractiveness of the BaaS model. With most new cars being leased, EV ownership will become larger in the second-hand market. However, as BaaS vehicles enter the second-hand market without a battery this could create an opportunity for the BaaS model to be extended to the second-hand car market.

[49]The residual value refers to the resale value of the vehicle at the end of a lease agreement.

Consumer choice lock-in may weaken market entry for BaaS

There may also be some reluctance from consumers to engage with BaaS and move to different charging models if they are just getting used to the current EV charging infrastructure. An industry source said that "customer sentiment would be quite suspicious" of BaaS and there is uncertainty in how it would be received. They therefore highlighted the importance of being very targeted about where the technology is first trialled and the customers that are on-boarded. Additionally, with the majority of people not driving more than 20 miles or so a day, an industry source further questioned the uptake of the BaaS model. Halfords' Andy Turbefield added that consumer "confidence can be misplaced and out of date" due to a lack of education from the automotive sector and the media around EV battery life, range, charging times and cost. However, BaaS could benefit from this "misplaced confidence" in addressing EV concerns.

There are a range of barriers to the initial success of BaaS, according to Felicity Latcham at OC&C Strategy Consultants, including the density of demand, variety of battery types and consumer trust around a brand. This is likely to drive a comparatively high price for a limited product in the short term. Latcham adds that while BaaS addresses a number of consumer concerns around EVs it is unlikely to become a mainstream solution in the UK over the next few years unless it also offers a significant saving to consumers. However, there are options through which these issues could be mitigated in the long-term and it is likely to be viable in the future.

The dominance of some EV car brands in specific countries could make it difficult for other companies to enter new markets or gain market share. Also, the unfamiliarity of a new brand may cause slow take up from customers. Particularly when it comes to technology, people tend to have more trust in a brand they know and are familiar with.

Like with many forms of technology, the industry will look to the East, and if NIO and others can prove it can work in as large a market as China, investors might demand European and North American contemporaries to do the same. However, an industry source noted that they would be "personally disappointed to see a lot of investment go into infrastructure for one brand" if that is how battery swapping was to develop and be rolled out in the UK.

Reductions in the range and charging speed advantage of BaaS over EV charging

Rapid charging technology is improving with some fast-charging stations providing 80% charge in 30 minutes and a Tesla supercharging station providing up to 200 miles in 15 minutes. With faster charging likely to improve further in the coming years, the time saving on swapping a battery compared to charging will be reduced. While a battery swap, which takes three to five minutes currently, is more time efficient than fast and standard charging stations, this efficiency is likely to decline as both battery technology and charging technology improves. However, it is worth noting that any improvements to faster charging could put constraints on the grid, which is where a BaaS model could prove more advantageous.

The make-up of urban environments and infrastructure influences the potentials for BaaS in markets across the world

Chinese infrastructure and housing stock supports the BaaS model well, with apartments being the most common housing stock, particularly in urban areas. This limits accessibility of home charging for EV users, meaning that battery swapping can be speedier and more convenient than using charging stations. However, in the UK, 80% of households live in houses, making home chargers more accessible for EV users. The 'successes' of battery swapping will be very much determined by the type of housing stock in a particular area, or indeed country, and therefore the access to EV home charging, as well as the potential for other charging solutions e.g., local charging hubs.

Long-term exclusivity of contracts, for example between charge point operators and motorway service areas, could limit the potential for installation of battery swap stations at such sites. At present, this issue is on the government's radar in the UK. In March 2021, the government said it would act to increase competition in EV charging options at motorway services stations. A year later, in March 2022 the Competition and Markets Authority (CMA) stepped in actively on this matter as it closed its investigation into Electric Highway's long-term exclusive contracts with commitments from Gridserve to not enforce exclusive rights in contracts with Extra, Moto, or Roadchef after November 2026, reducing exclusive contracts with Moto and Roadchef by two and four years, respectively. The CMA also published an open letter to chargepoint operators and motorway service area operators, stating that closure of the investigation does not prevent it from taking further action where it suspects infringements of competition law.

Grid constraints are an additional challenge with regard to the location of battery swap stations, particularly those at a local level with stability problems on power networks. This means the system would be unable to cope with the intense amount of energy required at the swap station and therefore may limit the sites available for battery swap stations. Government commitment to fund grid upgrades will be important to ensure battery swap stations can be located strategically. Even currently, many 'critical' motorway services require expensive increases in grid capacity prior to the installation of additional chargepoints. The government's £950mn Rapid Charging Fund will go some way to fund these grid upgrades, but questions remain whether these upgrades would also meet the needs of battery swap stations.

Threats to resource accessibility could undermine the market for batteries in the short- to medium-term

Geo-political issues could make accessibility of resources difficult, particularly for battery components, with the lithium and nickel supply chains strained by international tensions. Increased battery recycling should help mitigate this risk; however, it will not be a short-term solution as battery recycling facilities need to ramp up. Elon Musk recently, at a Financial Times Future of the Car Event, speculated that Tesla's supplies of raw battery materials may become strained beyond 2025. Similarly, EV battery manufacturing capabilities will need to become less reliant on other countries, with UK capabilities specifically needing to increase.

Questions around the sustainability of battery swapping risks undermining the case for BaaS with corporate customers focused on ESG factors

With corporates becoming more environmental, social and corporate governance (ESG) focused, another issue for BaaS is how corporates see the environmental footprint of battery swapping and its efficiency, particularly in terms of the surplus number of batteries that need to be held to meet demand and the under-utilisation of the batteries.

More favourable engagement from the UK Government is required at this stage

Previous successful BaaS model roll outs have involved engagement from national government (see section 3.1). In the UK, the scale-up required to introduce the technology will need significant investment which is unlikely to be unlocked without government intervention, such as through partnerships or subsidy support. The current UK Government stance is that battery swapping poses various technological challenges, including the need to standardise battery size and in-car position between different vehicle makes and models and to produce more batteries than vehicles[50]. It believes the commercial case for battery swapping is yet to be proven, especially as EV range and charging speeds improve. However, it says it watches developments across all EV technologies with interest.

[50] Common misconceptions about electric vehicles | GOV.UK

4.2. Feasibility for BaaS in the UK

The model fulfils key consumer concerns around EVs such as upfront cost and range anxiety

According to Jonathan Smart at Shoosmiths, "there is real promise for BaaS on the basis that it fulfils a clear consumer need". The perceived difficulties are effectively the same as those that many thought would not be overcome for chargepoint operators. Now there are significant resources being poured into network expansion by established players and market newcomers alike. With this in mind, Smart said he does not think the obstacles to BaaS are "insurmountable" and can see BaaS "becoming more mainstream before the decade is out" especially as traditional forecourts have to change their business model anyway with more chargepoints.

Smart added there could be a future for BaaS in the UK, but for this to happen, the issues of lack of standardisation of batteries and achieving scalability across the country in both urban and rural areas would need to be addressed. It is also crucial that a common standard and licensing process for a project of this scale is decided upon.

The model can function as complimentary to, as opposed to a challenger for, other EV and chargepoint types

It is feasible, if not necessary, for the BaaS model to co-exist with chargepoint infrastructure and, as with the NIO model for EVs, to have the capability to use both battery swap stations and chargepoints. An industry source said the technology is "additive" and won't "take away from what's already out there and what's already being put in the ground". In order for this to happen in the UK, BaaS would need to have a strategic and focused rollout. The risk of a national roll out is that BaaS EV sales are spread unevenly across the UK meaning that greater investment would be needed to build swap stations across the UK to accommodate the dispersed use of the service. If 100 BaaS EVs were sold but in 100 different locations around the UK, that is not going to work as a start-up model, according to an industry source. BaaS EV sales would need to be focused on specific areas of the UK allowing for battery swap locations to be more targeted and efficiently used. Pilot projects of the technology in specific areas would also help to gauge what the customer engagement might be with the technology as it is difficult to get a perception of this at the moment with it being so nascent. With the Action Net Zero[51] project in Bristol, an industry source suggested this could be a good place to launch the BaaS model as the city is already engaged with accelerating the transition to EVs and making charging more accessible.

A key approach for the BaaS model in the UK could be to enter the fleet charging market

Even if BaaS is not seen to be a viable option in the UK for domestic EVs, it could provide a charging solution for EV fleet cars, such as a taxi company, as a B2B BaaS proposition would have a "slightly different set of economics" according to Felicity Latcham at OC&C Strategy Consultants. This would negate the need for widespread battery swapping infrastructure as fleet vehicles tend to operate in specific areas or on specific routes with a controlled density of vehicles. Jonathan Carrier (ZipCharge) noted that the BaaS model could work for car rental firms where there is a large density of vehicles in a very close location and there is a quick turnaround time on the vehicles. There is often ample parking for swap station facilities and the sites can have full overview and management of the batteries and how that sits within the economic framework of the car rental business. However, Andy Turbefield (Halfords) noted that BaaS for fleets would only be a "huge benefit" if it significantly reduced the cost of the vehicle to the lease company.

> "BaaS EV sales would need to be focused on specific areas of the UK allowing for battery swap locations to be more targeted and efficiently used."

[51] Action Net Zero

4.2.1. Achieving the UK 2030 target

To meet the UK Government commitment to end the sale of new petrol and diesel cars and vans from 2030, it is integral that there is a comprehensive and competitive EV charging network in place that can be trusted and that consumers have confidence in. An industry source noted "we have got a long way into this journey already" and the government is "thinking of novel ways of using the infrastructure that exists already" but they added that "we need to keep on rolling out a conventional EV charging infrastructure". They also noted that "there's a big question about how fast new infrastructure needs to go in the ground". The rate at which the infrastructure is going into the ground is increasing, but there is a macro issue that is going on in the world right now in terms of supply of EVs and new vehicles in general.

The government estimates that 300,000[52] public chargepoints will be needed by 2030, a more than 10-fold increase in current numbers (approximately 29,600[53]). It also notes there will need to be a 'suitable mix of different types of charging' across the UK. It noted the importance of rapid chargers on longer journey routes, such as motorways and in remote areas, and on-street charging for those without driveways and garages. However, "the conversation in the UK about the different types of charging infrastructure that is already out there is not very nuanced" according to an industry source, and there is a "postcode lottery" on access to suitable charging that risks areas of the UK "falling behind".[54] There is an air of concern that the 2030 chargepoint modelling will not be reached. If the general public perceive that the EV charging network will not be adequate to support EV growth or that its roll out is not going to plan, then this will have significant impact on the take up of EVs. Jonathan Carrier (ZipCharge) highlighted that the number of chargepoints is not important, what is more important is their location, accessibility, and interoperability, and whether they are matched to dwell time. He added that there is a "significant gap between perceived need and an actual need on the consumer side". There is "very limited private investment" into AC EV charging due to low utilisation of chargepoints, low returns, and a long payback period, according to Carrier.

Another issue affecting the 2030 target achievement is that over 25%[55] of drivers do not have access to a driveway or garage and therefore cannot install a home chargepoint. This highlights the importance of on-street charging for both accessibility and cost, as rapid charging can cost around 60% more than home charging. The government highlighted that a 'step change' is needed to deliver the on-street charging required to encourage EV take-up whereby local authorities will need to play a key role, but it will require sufficient equipping and support. Similarly, relatively little is spoken of the equity of the access to EV charging tariffs in the UK. Those that have their own home, or access to home charging, and use 'time of use tariffs', where it is cheaper to charge overnight, face lower charging costs than those that do not have access to a driveway and have to rely on using public chargepoints, which are much more expensive because of their higher set up costs and that they are seen as being convenient and 'on the go'. The BaaS model could help address this issue.

Jonathan Carrier at ZipCharge believes that the "biggest elephant in the room" affecting the achievement of 2030 targets is the gap between rural and urban charging, where EV users living outside of a city are being "totally forgotten about in the world of EV charging".

[52] UK electric vehicle infrastructure strategy | GOV.UK
[53] UK electric vehicle infrastructure strategy | GOV.UK
[54] Electric vehicle charging market study | Competition & Markets Authority
[55] Electric vehicle charging market study | Competition & Markets Authority

4.2.2. Future EV charging options

The CMA acknowledged in its Electric Vehicle Charging Market[56] study that strategies, plans and measures for the development of EV charging must be flexible and responsive. Consequently, charging networks must be open and interoperable and the ease of use by all drivers and brands of EVs is 'fundamental'. This does not bode well to government support for a BaaS model where, realistically, battery swap stations will only be suitable for certain EV models. Also, reference from the CMA to the development of subscriptions and bundling from chargepoint operators makes it confusing and harder for consumers to compare and understand deals and signifies little excitement from the offset on the subscription service that the BaaS model would likely bring.

There has been mention from the UK Government that wireless or inductive charging could offer an alternative to plugs and chargepoints. However, with reference to the technology being 'still relatively commercially immature'[58], similar sentiments would be expected towards the BaaS model. An industry source said that they see the future of BaaS in the UK in the same light as wireless charging for EVs.

With battery technology improving, battery degradation is becoming less of a problem and battery technology will continue to evolve, according to Andy Turbefield (Halfords), meaning the need for battery swapping declines. Charging infrastructure is also growing, including that of fast charging points. Although most EV users are charging their vehicles at home overnight, as the EV roll out progresses, charging for residents in flats with no off-road parking will be more difficult, so having BaaS might increase the EV uptake for these users, particularly in urban areas.

Some could argue that the government is putting all of its eggs into one basket and focusing too much on chargepoint infrastructure instead of looking at alternatives that could fill the gaps which are left exposed by the challenges surrounding the chargepoint roll out. More flexible solutions that charge at different rates and different speeds, that all match time and locational needs for consumers, is "ultimately the only way to deliver a balanced network", according to Jonathan Carrier (ZipCharge).

It is important that the network flexibility that BaaS can offer is not overlooked when assessing the future EV charging infrastructure. This is particularly important as the UK moves towards its net zero target and intermittent renewable technology on the system increases and the role of battery storage becomes increasingly important.

[56] Electric vehicle charging market study | Competition & Markets Authority

[57] CBP-7480.pdf (parliament.uk)

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