Challenges and Opportunities for Car Retail Business in Electric Vehicle Charging Ecosystem

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***Abstract*—Mainstream electric vehicle adoption (EV) is essential to decarbonise the transportation sector. Car retail business needs to be transformed in many countries to meet legislative requirements that ban the sale of new petrol and diesel cars. To that end, this paper surveys the opportunities and challenges for car dealerships who could become key players in transport electrification. The challenges are identified as deploying charging infrastructure at business sites, keeping EV batteries healthy until they are sold, and lack of standards and protocols for chargers and communication systems. On the other hand, right investments could make car dealers main players in the energy markets. A number of opportunities, including providing ancillary services and public charging access, as well as reuse of old EV batteries, are discussed in detail. Such considerations are critical in this early stage of designing charging stations for the future of net-zero economies.**

***Index Terms*—EVs, retail business, Vehicle to grid, battery degradation**

I. Introduction

Over the last decade, more than seventy percent of the global economy have set or are aiming a target of reducing carbon emissions to net-zero by 2050 [1]. Specifically, a net-zero future should be achieved by 2045 and 2050 in Scotland [2] and the UK [3] respectively, according to government targets. A considerable part of achieving these targets will involve decarbonisation of transport by the eradication of petrol and diesel cars and replacing them with electric vehicles (EVs) [4]. This strategy is reflected by the Scottish and the UK government targets, which mandate a ban on the sale of new petrol or diesel cars starting from 2030 [2].

It has been well-documented in the literature that uncontrolled charging of large-collections of EVs poses challenges to power systems (increased system peaks and additional stress on network assets) and costly network reinforcements are inevitable [5]. A further transformation is needed for vehicle retailers, as their businesses are not designed to sell EVs. To that end, the goal of this paper is to present opportunities and challenges for EV retail businesses who, due to their strategic real-estate locations, could become major players by providing grid and charging services, and interface between electricity sector and end users.

At present, two-thirds of the EV charging occurs at customer premises because most of the early adopters have access to private charging space. On the other hand, public charging activity is expected to grow by tenfold in Europe and half of the EV demand will be supplied by public stations [6]. EV retailers will play a critical role in the evolving EV ecosystem as they own critical assets that can not only sell EVs but also provide charging services. For instance, in the UK, more than 60% of the used cars sold are from nearly 5000 dealerships located across the country. An early implementation of electrifying car dealerships took place in Germany in which 53 AC and 2 DC chargers were installed [7].

Mass EV uptake will increase the demand on the electrical grid, which will require efficient load management to prevent costly grid reinforcements. Moreover, as the share of renewable energy increases, there is a strong need to increase load flexibility to cushion fluctuations in the generation side. Vehicle-to-grid (V2G) applications, which enable bidirectional power flow between groups of EVs and the power grids, present a plethora of opportunities [8] for retailers and grid managers alike. V2G could allow for better integration of renewable energies to the grid, better balancing of grid supply and demand, and offer monetary profit for those utilising this technology [8] by enabling their participation in the energy market.

The challenges for the vehicle retail businesses are related to hosting large number of EVs, maintaining their battery health, and designing on-site charging infrastructures. For instance, on average it takes more than 40 days to sell a car in a dealer in the UK [9]. Long parking durations under hot or cold temperatures will reduce the lifetime of the battery and reduce customer confidence. It is noted that the majority of the cities with high EV penetration experience long and cold winter months [10]. EVs parked at a retailer need to be connected to a charger to keep the battery at recommended temperatures (e.g., 20 Celsius). To support this, substantial investments may be needed to deploy chargers and other supporting network equipment commensurate with the capacity of the facility. Nevertheless, such investments could create an opportunity for retailers who are already in a position to transform their businesses by taking a major role in EV charging and V2G support and benefit from new revenue streams.

Battery degradation, as a result of cold weather [11], charging habits and general usage [8], is a major obstacle for the

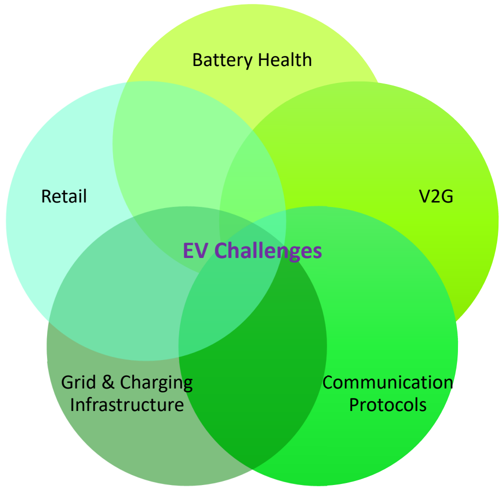

Fig. 1. Main challenges associated with mass introduction of EVs.

second-hand EV market. More accurate battery state of health (SoH) estimation techniques are needed to make fair valuation of used vehicles. This presents an opportunity for retailers to offer services in battery health evaluation using novel and accurate methods.

Standardization of enabling charging technologies is another major challenge for EV uptake. Communication protocols regarding charging infrastructure also pose challenges, which will only be exacerbated as EV ownership increases due to the heightened requirement for charging infrastructure. Finding the balance between open and interoperable communication protocols whilst upholding stringent cyber-security measures, which are critical to upholding consumer trust, will be important going forward [12]. An overview of challenges is demonstrated in Figure 1.

II. Challenges

A. Grid Connection and Charging Infrastructure

As the ban on the sale of new petrol and diesel cars comes into force in the UK [3], it is inevitable that there will be an increase in EV ownership. This higher uptake in EVs presents a challenge in the form of increased electricity demand [12], suggesting the current grid infrastructure may require upgrading to meet this rising demand. However, it is the physical space and cost of developing the necessary infrastructure to facilitate the hosting of EVs that will pose the greatest challenge to retailers.

Acquiring a fleet of EVs to sell will require charging infrastructure, not only to charge the vehicles themselves or to offer this as a service to clients, but also to allow for exploitation of practices such as V2G activity. Table I shows the costs relating to development of charging infrastructure in Germany, demonstrating the high upfront cost associated with making the switch from petrol or diesel cars to EVs for retailers. Ensuring that there is adequate charging that is compatible with the cars hosted by the retailer will pose a significant financial challenge. Note that the cost for deploying V2G compatible chargers is even higher. According to [13], a 7kW V2G charger costs about 660-1160 GBP and represents the biggest challenge for mainstream V2G applications. Moreover, other considerations/expenses such as street work, legal, and planning permissions may increase the total cost.

TABLE I
EV Charging Infrastructure Associated Costs in US Dollars, adapted from [14]

Cost Type	**Charger Type & Cost**		
	Regular, AC, 2-7 kW	***Fast, AC, 7-43 kW***	***Rapid, DC, 50+ kW***
Charging Equipment	225 - 789 USD	2,817 USD	16,900 USD
Installation & Grid Connection	0 - 563 USD	5,633 USD	11,267 USD
Total	225 - 1352 USD	8450 USD	28167 USD

Moreover, development of charging infrastructure requires significant physical space to host support network equipment. For example, a Tesla supercharger station which supplies two charging stalls would require an area of 25.6 metres squared in total to house the entire charging station. This area includes a medium voltage/low voltage transformer, typically situated around 7.3 metres away from the EV charging device [15]. This suggests retailers will need to ensure they have the space necessary to install such charging infrastructure, which may result in the need for expansion or reorganisation of retail premises and may in turn incurr an associated cost.

Limited network connection could be a major challenge for some retail locations which do not have access to high voltage or are part of an area that is served by a congested substation. In this case, alternative architectures such as on-site storage and/or generation could be used. In [16], a charging station equipped with an on-site storage model is developed. Another approach would be to employ smart charging and load management schemes, which could significantly reduce the infrastructure cost. This is because stationary EVs consume limited energy to warm the batteries. For instance, the experimental study presented in [17] shows that 5% of the stored energy is used by the battery management system of a Tesla without connection to a charger. However, this amount is different for each car depending on the pre-installed battery management system.

B. Battery Health

EV batteries have been shown to possess a relatively long lifetime, however, it is inevitable that they will become susceptible to degradation over time [18]. Battery degradation differs between batteries due to disparities in design and manufacture. Ghazanfari et al. [8] identify that it is the extent to which the battery is discharged that has the biggest impact on its degradation. This indicates that charging habits of the user could have a significant impact on battery health.

Cold weather is also identified as a cause of battery degradation by Jaguemont et al. [11]. When temperature is low, power and energy loss can occur due to the reduced reaction rate of electro-chemical processes. Therefore, cold weather can exacerbate battery degradation and reduce all electric range.

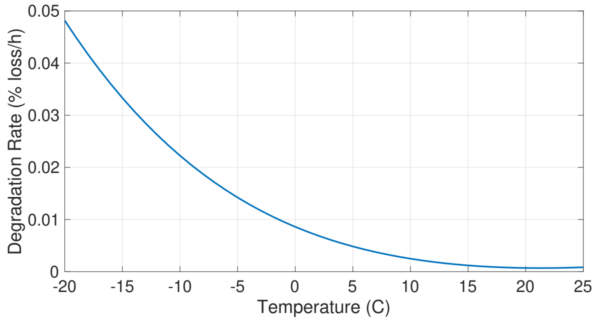

Fig. 2. Battery degradation rate for off-grid parked EVs.

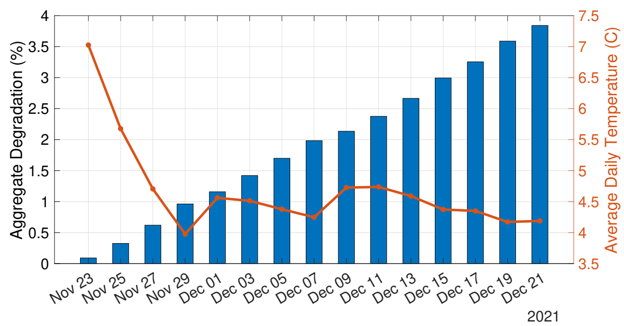

Fig. 3. Percentage of battery degradation of a parked EV in Glasgow, UK.

To prevent degradation, thermal management systems heat the battery. However, when an EV is not connected to a charger for long hours, noticeable irreversible degradations, also known as calendar losses, can be observed. In [11], a calendar model is developed to quantify battery aging at low temperatures. The regression model shows the loss degradation rate (% of loss per hour) as a function of temperature and is written as,

$$L(T) = c_1 T + c_2 T^2 + c_3 T^3 + c_4 T^4 + c_5,$$

where the T denotes the temperature and polynomial constants have the following values; $c_1 = -0.0009224$, $c_2 = 3.71 \times 10^{-5}$, $c_3 = -6.6 \times 10^{-7}$, $c_3 = 6.23 \times 10^{-9}$ and $c_5 = 0.0086$. Loss degradation function $L(T)$ is evaluated for $T = -20, ..., 25$°C and results are presented in Fig. 2. It can be seen that degradation rate significantly increases in subzero temperatures.

To better understand the impacts of degradation, Fig. 3 presents cumulative battery losses for an EV battery parked outside in Glasgow, UK for two weeks (Nov 23 – Dec 21, 2021). Loss function $L(T)$ is evaluated using hourly temperatures. As shown in Fig. 3, irreversible battery loss reaches 3.96% in just four weeks. It is noted that total degradation could be higher when it takes longer to sell a vehicle. Moreover, degradation impacts will be more severe for other regions (e.g. Canada, Norway) with colder temperatures.

EV batteries are designed to prevent excessive degradation caused by the discharging process through "buffering" which prevents the user from utilising the full amount of power stored. This decreases the number of charge cycles (full charge to full discharge) experienced by the battery, which preserves its lifetime [18]. However, techniques such as V2G which revolve around charging and discharging of the battery, could therefore have a detrimental effect.

C. V2G Technology

V2G is a bidirectional charging mechanism, meaning energy can be taken from the grid to charge the EV battery and can also be taken from the EV battery and discharged back to the grid [19]. Although this presents a plethora of opportunities for EV retailers, there are a number of challenges associated with V2G.

V2G could pose a battery health challenge due to the repeated charging and discharging. A study by Thingvad et al. [20] found that applying V2G technology to a battery across five years could result in the SoH reducing by 15.7%. In [13], the kWh capacity degradation per kWh discharge is assumed to be 0.0003 for an 80 kWh battery. This means for a one-hour V2G session with 10 kW bidirectional chargers, the battery degradation would be 0.004%. By considering the typical time-to-sell duration, if an EV participates in forty V2G sessions (one session per day), then the total degradation would be 0.15%. In [21], an empirical study to examine battery degradation from V2G services is presented. Using 10kW V2G chargers at various rates, frequency regulation was delivered for 15 hours per day with daily energy transfer of 50.6 kWh. The results show that EV battery capacity is reduced by 10% in two years and 17.8% in five years. This shows that battery degradation due to V2G sessions is significantly less than degradations stemming from cold weather.

Ghazanfari et al. [8] express a need for smart charging algorithms to be used during V2G activities in order to mitigate damage to the battery, indicating that use of V2G technology without causing damage to the battery may be complex. Work presented in [8] also states that different V2G operations will have different impacts on the battery in terms of degradation, with some having negligible impact. This suggests that V2G challenges surrounding the health of the battery will not necessarily affect every user, depending on the type of V2G activity executed.

D. Standards and Protocols

Standards and protocols play a key role in the penetration of new technologies. Despite the growing interest towards EVs, a substantial amount of improvements is needed to ensure interoperability and security of the charging infrastructure [8]. Standardisation is further required for scalability of the EV retailers and other facilities, effectively presenting V2G as a service.

Currently, there is no universal standard for charging connector types and variety in connectors creates compatibility issues. To overcome this, there is motivation towards making the Type 2 connector the standard in Europe [22]. Moreover, V2G is currently only functional with the CHAdeMO connector type [23], restricting the potential for V2G to be introduced in the mainstream at present. There is work underway to make V2G compatible with the Combined Charging System (CCS) connector [23], which is regarded as the most adaptable connector type [22]. This could allow for V2G to be rolled out en masse, but other barriers may remain.

One of the most important standards is related to communications. Management of EV charging necessitates collaboration and communication between mobility and energy organisations. Communication protocols give guidance for communication and exchange of data to allow for good charging management and vehicle-grid integration [12].

Neaimeh et al. [12] state that communication protocols with high levels of interoperability and openness are preferable. Interoperability is defined as the extent to which numerous systems can collaborate freely. Openness can indicate whether the protocol has been created by an "accredited standards organization", whether it is liable to "intellectual property rights" or whether it is attainable in the public domain at little or no cost. For example, an advantage of having high interoperability would be that the owner of an EV fleet would not be restricted to selecting specific types of charging points due to the brand of cars within the fleet and, therefore, would not need to replace charging infrastructure if the car brand changes. High openness allows companies to work together on common ground, reducing individual companies' output and allowing them to reallocate resources towards tailoring their services to their consumers to gain a competitive edge [12].

However, the use of multiple different open communication protocols can fracture the charging infrastructure. At present, individual companies are creating and implementing their own, independent communication protocols. Clearer guidance on the use of protocols could allow for an international standard to be reached, which may help overcome this challenge. Previous literature [24] also highlights the existence of a cyber-security challenge with regards to charging communication protocols. These protocols, which could be utilised during V2G processes, may cause concern amongst users surrounding their data privacy. Metere et al. [24] recommend that communications are encrypted and that data is anonymised to prevent cyber-security challenges from acting as a dissuading factor for consumers.

E. Business Landscape

The shift to a net-zero future will also be felt in the retail sphere. A study by Cahill et al. [25] considered the sale of EVs from a dealership's point of view and found that EV buyers were generally less satisfied with their dealership than petrol car buyers. EV buyers were also more demanding in terms of requiring product knowledge and support from their dealership. This, in tandem with the lower customer satisfaction, implies that dealerships are not equipped with the knowledge or expertise necessary to easily sell an EV. Furthermore, the EV buyer's heightened support needs suggests that they require reassurance in making their purchase, perhaps due to a lack of trust in the technology.

This finding is echoed in a study by Pedrosa et al. [26] which interviewed drivers of petrol cars to gauge their attitudes towards second-hand EVs. Some respondents seemed apprehensive about EV technology, with one quoted as saying "*At this moment the state of technology… I don't trust it much*". This suggests that retailers may have to take on a more reassuring role and provide information surrounding EV technology to help foster both the new and used EV retail market.

TABLE II
POTENTIAL ENERGY MARKET APPLICATIONS FOR V2G

Type	Response	Duration	Revenue	Notes
Frequency Service	0-30 sec	0.5-30 min	$$$$$	Frequency Regulation and Restoration
Reserve Service	5-240 min	0.5-4 hour	$$	Fast, Short-term, Demand Turn-up
Capacity Market	$\leq$ 4 h	unlimited	$$$	Need to meet system demand
Behind the Meter	N/A	15-120 min	$$$	Peak shaving Higher Renewables

As discussed earlier, EV battery health and degradation also pose challenges for retail. Previous literature [27] highlights that EV valuation models used by dealers of second-hand cars are still in their infancy. Since a significant proportion of an EV's value is determined by the state of its battery, it follows that a regulated method of quantifying the battery health will be key to ascertaining its resale price. Since battery State of Health (SoH) and State of Charge (SoC) are not standardised indicators [27], meaning that there are no strict regulations or guidelines in place for those who conduct measurements of either of these entities. This, therefore, makes a comparison between EVs less reliable and compromises the validity of valuations made by retailers.

III. OPPORTUNITIES

A. Additional Revenue Through Energy Markets

Despite the challenges associated with V2G, the use of this technology also presents a multitude of opportunities, highlighted in Table II. The ability to charge and discharge energy from and to the grid allows a monetary profit to be made by enabling V2G users to participate in the energy market. The EV battery can be charged at times of low demand, when energy prices are usually lower. This energy can be stored in the battery until times of peak demand, at which point the electricity can be discharged back to the grid, therefore allowing the user to sell energy when prices are at a premium [8].

V2G technology also allows for better management of the energy resources. By using EV batteries as a means of storage, at times of surplus generation, V2G would allow this energy to be stored and introduced back to the grid at a time when it is in greater need. This could allow for a better supply and demand balance to be reached, which may in turn assist regulation of other grid attributes such as frequency. Furthermore, utilising EV battery storage capacity means operating costs of the grid could decrease as the need for construction of storage is eliminated [8]. More specifically, V2G can be used for congestion management for distribution network operators and

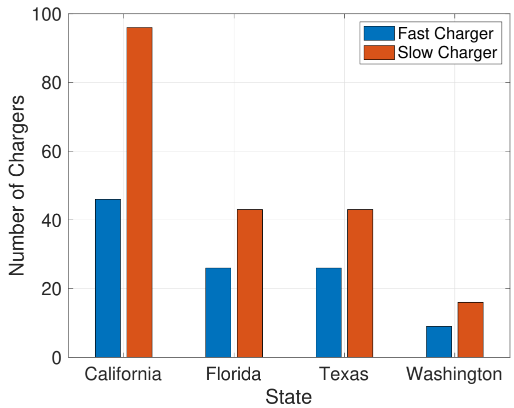

Fig. 4. Number and type of public chargers deployed at car dealerships in the US (Ref: [29]).

it is estimated that the value per EV could be at least 250 GBP/EV.year [13]. Other revenue streams include participation in Frequency Response and Arbitrage markets.

The use of EVs as energy storage can also facilitate better integration of renewable energies to the grid [8] which is key to unlocking the full potential of EVs to decelerate climate change. Since renewable energies are more likely to have variable generation [28], it is likely there will be times of excess generation and also of lack of generation. V2G, again, allows for charging and discharging informed by generation and demand, which could increase the share of grid electricity generated by renewable sources.

Although V2G could exacerbate battery degradation, there is some evidence to suggest that battery health could actually benefit from V2G activity. A study by Uddin et al. [30] developed a model to assess whether the benefits of V2G techniques outweighed the potential degradative impact on the battery. The model accounted for entities such as calendar age of the battery, its SoC and temperature. The model also operated on the basis that a smart charging algorithm was used, mentioned in Section II-C. It was found that the overall impact of V2G on the battery was positive, with the modelling suggesting that both a reduction in capacity fade and power fade was possible. Furthermore, Project Sciurus [23], which aims to introduce V2G technology to the UK, claims that use of V2G can give better battery management. Algorithms used in V2G can allow the battery SoC to return to a "mid-position", preventing the EV battery from remaining at extremes for extended time periods, which would contribute to poor battery health.

B. Public Charging Service

EV retailers could build new capabilities and offer public charging service to both fleets and the public to meet the exponentially growing EV charging demand. The amount of public charging is expected to grow tenfold by 2030 mostly because some new EV owners will not have access to private charging. Moreover, the EV charging pool is expected to reach 20 billion USD by 2030 and EV dealerships could

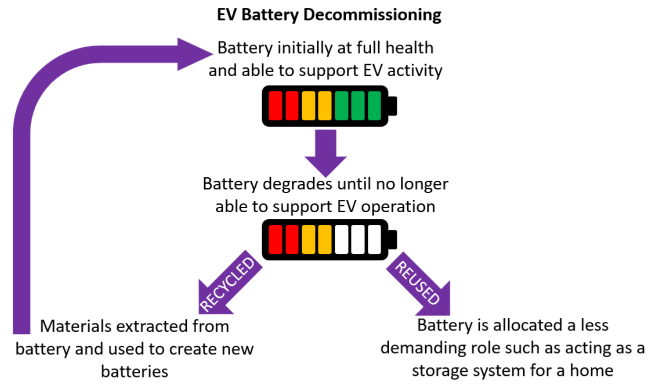

Fig. 5. Sustainable options for decommissioning of EV batteries.

play a leading role in this emerging market [31]. In the US, a number of car dealerships have started to provide public charging services. In Fig. 4, statistics about dealership charger services for different states are presented. Note that most dealers typically host a single charger and the presented figures correspond to less than 10% of the all car retailers in each state.

C. Retail

Despite the difficulties retailers face in selling EVs, Kempf et al. [32] suggest that retailers could make profits through offering lucrative new services and products such as "battery-boosting software" and "advanced driver-assistance systems". Furthermore, by providing training for technicians to deal with EV specific tasks, technical support services can be created and offered to clients, further capitalising on aftersales revenue. Retailers also have the opportunity to train technical staff to conduct battery certification services [32] which could give clients the ability to evaluate the health of their EV battery, and therefore estimate the value of their vehicle. Conducting these services for a fee would act as another source of profit but would also develop accuracy of pricing in the second-hand EV market. By consolidating valuation strategies in the used EV market, the opportunity to widen access to EVs is posed. The price of a new EV is outwith the budget of many and a second-hand model presents an affordable alternative [33]. Making pricing of these models fairer and more consistent will enable a more widespread shift to EVs.

D. Battery Reuse and Recycle

Battery degradation could be a significant challenge to widespread introduction of EVs. However, as battery health degrades to the point where EV operation can no longer be supported, there may be the opportunity to repurpose the battery. EV batteries have relatively large capacities. Kotak et al. [34] report that a capacity of 44 kWh is possessed by the average EV battery, with some models having a battery capacity of up to 100 kWh. Therefore, as the battery degrades so that optimal EV function is no longer feasible, repurposing the battery is a viable option. For example, the batteries can contribute to storage systems for renewable energies and could supply the electrical grid or an individual residence [18] (shown in Fig. 5).

IV. Conclusion

This paper reviewed the opportunities and challenges for car dealerships in the emerging EV ecosystem. Car retail business needs to be transformed in line with recently introduced legislation on EVs. The main challenges in this transformation include investing and designing on-site charging infrastructure, preserving battery health, and adopting the appropriate standards and protocols. It was further presented that if EVs are kept under cold weather without connecting them to a charger, the irreversible battery degradation would be significantly higher than the degradation that would occur due to V2G sessions. On the other hand, a number of opportunities were identified and discussed in detail. Car retailers could become V2G and public charging hubs. In both cases, the retailer maximises financial benefits depending on the infrastructure cost.

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