Vehicle-to-grid in the UK fleet market: an analysis of upscaling potential in a changing environment

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Highlights

- User-centered analysis of market dynamics in socio-technical transition
- Fleets are a potential domain for the application of V2G
- Fleet market trends have contradictory implications for V2G uptake
- Changes in fleet management practices and vehicle use patterns are influential
- Labour relations with drivers could impact V2G potential

Keywords: Vehicle-to-Grid; Fleet market; Sustainability Transitions; Users; Markets; Transport

Word count including tables and captions: 8033

Abstract

Vehicle fleets are considered an important context for the deployment of innovations such as electric vehicles and vehicle-to-grid (V2G) technology. Fleet vehicles constitute a significant share of vehicle registrations, yet little research has been conducted into how the make-up of the changing fleet market could influence upscaling of innovations. This paper presents an in-depth study of the fleet market in the United Kingdom that assesses synergies between V2G and vehicle fleets by analysing socio-technical trends. The approach taken allows for analysing the role of users and markets in upscaling socio-technical transitions. The paper provides a system-level account of the fleet market, and shows how changing user characteristics, the rise of telematics, Low Emission Zones and changes to business operations and labour relations present specific drivers and challenges for V2G. It is concluded that use-related changes in the market environment are highly influential in shaping the upscaling trajectory of sustainable innovations such as V2G.

1. Introduction

CO_2 emissions in road transport have been rising in recent years and are now responsible for 19% of all European emissions (EEA, 2019a). It is increasingly accepted that a fundamental transition is required in the social and technical elements of the transport system (Geels, 2012), which will likely include a closer integration with the energy sector. Vehicle-to-grid (V2G) could potentially reduce environmental impacts of both the transport and energy sectors. V2G concerns the deployment of electric vehicle (EV) batteries to store electricity from the grid and feed it back to the grid at an appropriate time (Kempton & Tomic, 2005; Sovacool et al., 2018). V2G can help stabilize electricity grids by providing back-up capacity during unexpected outages and assisting with frequency regulation. The storage capacity provided by V2G can also facilitate the introduction of intermittent renewable energy sources such as solar and wind (Noel et al., 2019). Challenges in implementing V2G include potential battery degradation (Dubarry, 2017; Thingvad and Marinelli, 2019) and uncertainties about economic benefits (Peterson, 2010; Freeman, 2017). The time a vehicle is plugged-in has been mentioned as key determinant of economic viability of V2G (Cenex, 2019).

Fleets, or vehicles used by businesses and other organizations, are often identified as a particularly suitable application domain for V2G. Fleets could provide economies of scale and the limited and predictable use patterns of fleet vehicles would fit well with V2G (Hein et al., 2012; Dijk et al., 2013). Fleets are also influential in shaping the development trajectory of road transport. Around 50% of all new passenger vehicles in Europe are registered to companies, which amounts to approximately 8 million vehicles (ACEA, 2020; EEA, 2019b). Moreover, many fleet vehicles enter the second-hand private market when lease cycles are finished. Fleets, for these reasons, are influential in shaping the development trajectory of the road transport sector.

Studies on the potential introduction of more sustainable vehicles in fleets have tended to focus on the decision-making process of fleet managers (Sierzchula et al., 2014; Wikstrom et al., 2016; Skippon and Chappell, 2019). In a recent review, Demeulenaere (2019) identifies operational and implementation barriers which may limit the introduction of alternative fuel vehicle technologies in fleets. Battery constraints which conflict with driving schedules are seen as main operational barrier but high up-front costs, lack of infrastructure and inadequate information provision are important as well. There also appears to be considerable variety in decision-making processes and barriers to low-emission vehicle adoption in fleets across organizations. These differences are especially apparent between smaller and larger (Nesbitt and Sperling, 1998; Sierzchula et al., 2014; Boutueil, 2016) and public and private sector organizations (Nesbitt and Sperlling, 2001).

Important user-related changes are currently underway in the fleet market. Despite having a 'conservative' image, fleet management has changed considerably in the past decades, with the demise of the traditional fleet manager and increased outsourcing of associated responsibilities (Venson, 2018). Other important developments include changes in types of fuel used, the rise of delivery freight (Cui et al., 2015), increasing use of telematics for tracking vehicles (Nijkamp et al., 2016), and introduction of environmental zones in cities (Browne et al., 2005). Although these changes feature extensively in various market reports, they have only been considered intermittently in academic publications and their direct and indirect impacts on the fleet market are expected to shape the upscaling potential of EVs and innovations such as V2G in important ways. Nonetheless, it is as yet unclear how those changes will affect upscaling potential . The corresponding aim of this paper is to explore the upscaling potential of V2G in fleets, given changes occurring in the fleet market.

The sustainability transitions literature is used as a theoretical starting point, as it has extensively examined how social and technological changes shape the use of low-carbon innovations (Köhler et al., 2019). Empirically, the study draws on document analysis and interviews with fleet managers and experts in the United Kingdom (UK). This qualitative approach was chosen because of the hitherto limited scholarly attention for V2G in the fleet market. The UK is an interesting site for exploring these issues as it is host to a number of the V2G test projects underway worldwide (HVA, 2018) and the government has laid out a long-term strategy for zero-emission mobility (DfT, 2018a). The research was conducted as part of Vehicle-to-Grid Oxford (V2GO), a demonstrator project investigating the viability of implementing V2G in fleets (Innovate UK, 2017).

The paper makes three main contributions to the scholarly understanding of fleet markets and the upscaling of innovations such as V2G. First, by providing a systemic account of current changes occurring in the fleet market and their influence on innovation adoption it goes beyond existing studies which have tended to concentrate on the decision-making processes of fleet managers. Since fleets account for approximately half of all new vehicle registrations in Europe, a better understanding of the fleet market is a useful addition to literatures on sustainability innovation and transport. Second, research into V2G has so far concentrated on privately owned cars (Sovacool et al., 2017, 2018). While fleets are often mentioned as suitable for V2G (Hein et al., 2012; Dijk et al., 2013), there is currently very little empirical insight regarding the extent to which different organization contexts might enable and constrain V2G. Third, the study advances existing analyses of markets for innovations in the field of sustainability transitions (Köhler et al., 2019; Boon et al., 2020), by employing a user-centred analytical framework for assessing upscaling potential of socio-technical innovations among business users.

2. Research concepts

The potential trajectories of and the difficulties innovations might encounter in upscaling are receiving increased attention in sustainability transition studies, particularly among those adopting more anticipatory approaches (Van Waes et al., 2018). The embedding of innovations in broader markets forms an important part of the upscaling process (Boon, 2019). Markets have been defined as "social arenas where firms, suppliers, customers, workers, and government interact" (Fligstein & Dauter, 2007, p. 107). Dewald and Truffer (2011, 2012) argue that market formation processes need to be analysed as evolving socio-technical systems, emerging out of interactions between various technological, institutional, political and user-related elements, rather than as "mere market structures". They identify the development of market segments, market transactions and user profiles, which include user preferences and agency, as important processes in market formation. Although the active role of users in new market formation has been previously considered (e.g., Meelen, 2019), broader demand-side dynamics in mature markets remain under examined. This study accordingly concentrates on user-related developments in an established market.

To grasp the dynamic nature of markets, we introduce the notion of socio-technical trends, and see the fleet market as constituted by various trends possibly influencing V2G uptake. This approach recognizes that the "social" and "technical" are always linked and dynamically co-evolve (Geels, 2005; van Bree et al., 2010; Dijk et al., 2013). A trend, meanwhile, is defined as "an inclination or a tendency that has been observed during the recent few years and that is expected to continue during the next few (3-5) years" (Jensen et al., 2014, p.7). Such an approach thus examines how tendencies evident in social, political, technical and economic settings may influence the likely uptake of an innovation. The current paper examines how developments in user preferences, usage patterns, user characteristics, technologies, infrastructure and policies are influencing V2G potential in the fleet market. This study concerns business users, which are defined as organizations and self-employed operators that utilize goods or services.

The sustainability transitions literature considers private users as creatures of habit who make choices based on limited information and social interactions rather than rational, well-informed, individual decision-makers. There is at least some evidence to suggest that such a conception is also applicable for business users in the fleet market. For example, it is reported that only a small share of fleet managers make total cost of ownership calculations for their vehicles. Instead, managers tend to rely on past experiences, endorsements by other fleet operators, acquisition cost and assessments of functionality when considering new fleet vehicles such as EVs (Nesbitt and Sperling, 1998; Mennenga et al., 2018). Changes in use patterns are likely to influence innovation upscaling drivers and barriers as well. Analysing EV potential, Truffer et al. (2017) discuss a scenario in which the sharing economy takes off and vehicles are used more efficiently and demand for small and robust cars increases. Similar trends could influence upscaling potential in business markets. For example, corporate car-sharing is an emerging trend potentially affecting fleet market use patterns (Fleury et al., 2017), which could in turn influence other innovation trajectories. Developments in user preferences and use patterns, therefore, need to be considered in assessments of the upscaling potential for V2G. Furthermore, research in the field of organization studies emphasises the importance of understanding how user characteristics influence the adoption and use of sustainable innovations.

User characteristics, in the current context, refers to the presence of small and medium-sized enterprises (SMEs) (<250 employees) and large companies (>250 employees) in the market. Organization studies research has shown that SMEs tend to have difficulties adopting and using sustainable innovations (Gallo and Christensen, 2011; Cassells, 2011). Although SMEs are a variegated group and implement innovations to address sustainability issues (Klewitz and Hansen, 2014), various barriers still exist for the 'long tail' of SMEs across sectors (Del Brio and Junquera, 2003; Walker et al., 2008). Identified barriers often relate to a lack of absorptive capacity and slack resources. Absorptive capacity refers to a firm's capacity to identify, evaluate and exploit socio-technical trends (Cohen and Levinthal, 1990). For example, SMEs might lack understanding of the benefits of new technologies or innovation subsidies. Slack resources can be defined as "the pool of resources in an organization in excess of the minimum necessary to produce a given level of organizational output" (Nohria and Gulati, 1996, page 1246). Facing outside pressures regarding sustainability, slack resources provide firms with capital to make additional investments needed for innovations. The availability of surplus resources might be particularly important in the case of V2G, given the capital-intensive nature of V2G infrastructure as well as additional costs associated with the purchase of EVs.

These various insights about market dynamics and business users informed the development of the guiding hypothesis[1] for this study: changes in user preferences, use patterns and user characteristics in the fleet market influence the potential to scale up V2G adoption in vehicle fleet contexts.

3. Methods

The research proceeded in multiple stages (Figure 1). An initial desktop study was conducted to obtain an overview of the fleet market and to identify ways of classifying fleet (Stage 1). Briefings and reports were collated from industry, consultancy firms, research institutes, government organizations and NGOs. Fourteen interviews were conducted with fleet experts and fleet managers in July-August 2018 (Table 1; Stage 2). A purposeful sampling strategy was adopted. Potential interviewees were identified during the desktop study and through consultation with a project partner with over 20 years of experience working in the fleet market. The fleet experts were based in academia and industry. These interviews covered the nature of the UK fleet market, approaches to operating fleets, current and emerging issues facing fleet operators and the potential introduction of EVs and V2G (see Supplementary Materials for interview schedules). Fleet managers were recruited from different sectors and types of organizations (e.g. public and private). These interviews focused on the role of fleet vehicles within their organization and approaches to managing vehicles and operating EVs. All interviews were digitally recorded and transcribed verbatim.

Materials collated during the initial desktop study and interviews were then analysed thematically by two of the authors independently through a process of inductive open coding (Saldana, 2015). This involved provisionally assigning descriptive labels and categories (e.g., management practices, telematics applications and vehicle replacement processes) to different fragments of text within the briefings, reports and interview transcripts considered potentially relevant to V2G upscaling (Stage 3). The authors then collaboratively classified, prioritised, integrated and synthesised their provisional codes in the qualitative data analysis program NVivo (Stage 4.a). In a second analytical step, the sustainability transitions literature, especially on users and markets, was reviewed and synthesised (Stage 4.b). The socio-technical trends framework, outlined in Section 2, was developed through this process and used to further guide the research and develop analytical explanations (George et al., 2005). The framework helped selecting, categorizing and explaining themes identified by the researchers. A first draft of the research results section was written based on this initial analysis and conceptual framework (Stage 5).

A second round of interviews was undertaken in July-November 2019 with seventeen fleet managers and industry professionals (Stage 6). A purposeful sampling strategy was employed with the aim of recruiting participants from diverse types of organizations. The fleet managers and industry professionals who subsequently participated were from different sectors and organizations of varying size. Of this group of fleet managers, all but one participated in the V2GO demonstrator project. The interviews covered fleet management practices, experiences and expectations regarding EV and V2G, expectations about sector trends and possible changes to fleet management (see Supplementary Materials).

The transcripts from these interviews were systematically checked and compared against the codes, conceptual framework and results generated during the coding and review and synthesis of the

[1] A 'guiding hypothesis' is used in qualitative research to generate questions and to search for empirical patterns and explanations in data (Marshall & Rosman, 2014). It provides researchers with a tentative direction while leaving open the possibility of the development of alternative explanations.

sustainability transitions literature (Stages 7.a and 7.b). This stage was designed to investigate the extent to which the 17 interviews corroborated or challenged these initial outputs. Although the second round interviews were mainly corroboratory, the effects of differences between the fleet management practices of smaller and larger firms became particularly evident. The implications of these insights are most apparent in the discussion of the specific challenges SMEs face in adopting V2G. The final stage of analysis involved an assessment of the level of impact of socio-technical trends on V2G's upscaling potential (Stage 9). Trends were evaluated in terms of the breadth (expected influence across different fleet market segments) and depth (extent of influence on decision-making of fleet managers) of their potential impact. Assessments were based on a combination of the views of the interviewed experts and the significance they were assigned in the different documents analysed (Table 2; Stage 8).

Given there is extensive debate about what constitutes a fleet, a broad definition is used. Traditionally, all vehicles owned or leased by organizations are considered to be fleet vehicles (BVRLA, 2016). Such a definition excludes 'grey fleets', privately owned vehicles used by employees or vehicles organisations provide to staff via financial mechanisms such as 'cash allowance schemes'. This analysis takes grey fleets into account because of their substantial number and the large uncertainties that exist regarding their operation (BVRLA, 2016). No minimum limit is set for a fleet size given the prevalence of small fleets within SMEs and the fact any boundary would be arbitrary. Fleets are often delineated by vehicle classes such as cars, light goods vehicles (LGVs) (<3.5 tonnes), heavy goods vehicles (HGVs), buses and coaches. As fleets of HGVs, buses and coaches are mostly operated by specialist operators and subject to highly particular regulatory structures, these fleets were excluded from the analysis. For the purpose of this study then, fleet vehicles are defined as all cars and LGVs used by organizations, irrespective of the vehicle ownership structure.

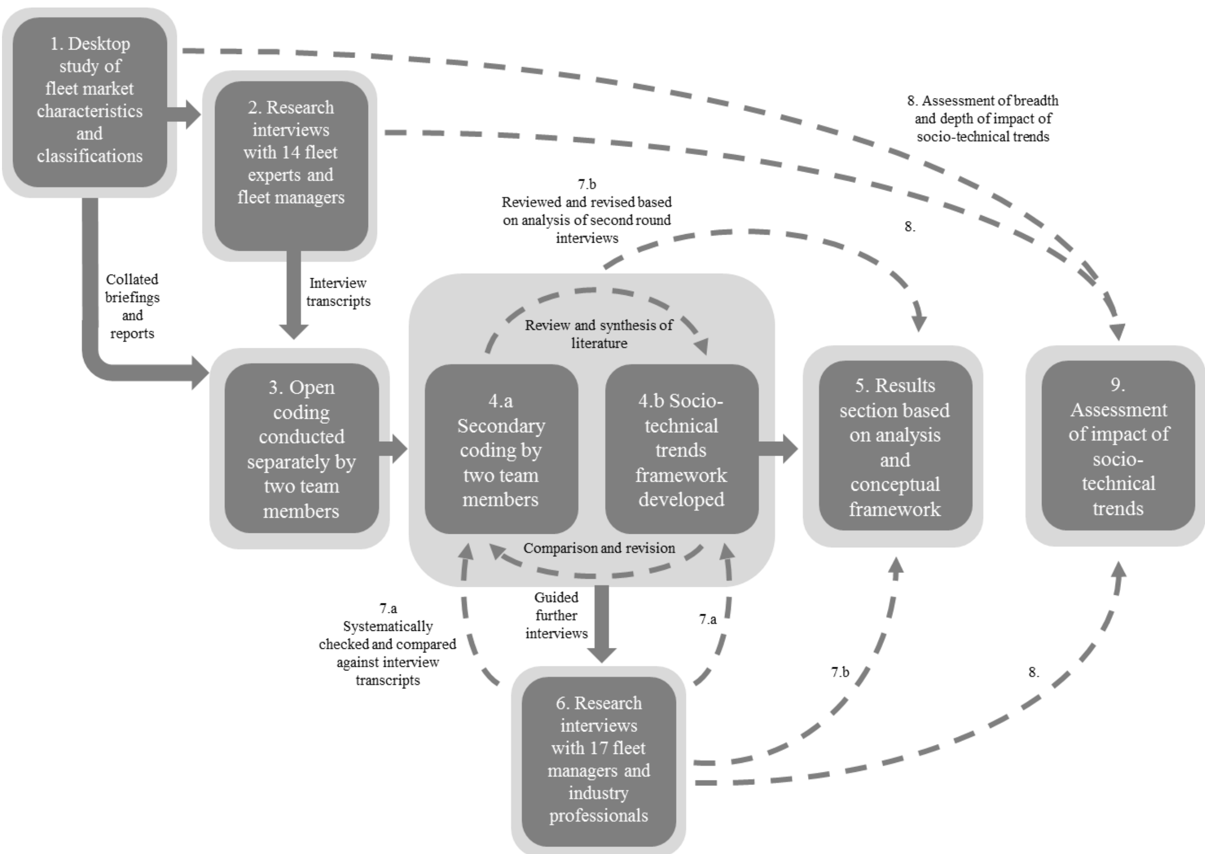

Figure 1 Overview of the multiple stages involved in the research

Table 1: Experts and fleet managers interviewed in May-June 2018 and July-November 2019

Interview number[2]	Type of organization	Current role	Experience
1	Fleet and leasing management consultancy	Director and consultant	Fleet expert
2	Academia	Professor	Fleet expert
3	Educational institute	Transport manager	Fleet manager
4	Vehicle leasing company	Manager	Fleet expert
5	Freight industry representative	Managing director	Fleet expert
6	Vehicle rental company	Divisional head	Fleet expert
7	Commercial delivery and postal services	Divisional head	Fleet manager
8	Automotive consultancy	Director	Fleet expert
9	Freight industry representative	Director	Fleet expert
10	Rental and leasing industry representative	Director	Fleet expert
11	Public transport service provider	Director	Fleet manager
12	Automotive management consultancy	Associate director	Fleet expert
13	Commercial delivery and postal services	Divisional head	Fleet manager
14	Emergency services	Executive officer	Fleet manager
15	Council	Fleet operations manager	Fleet manager
16	Large supermarket chain, online division	Operations development manager	Fleet manager
17	Recycling social enterprise	Director	Fleet manager
18	Library	Director	Fleet manager
19	Fire service	Business and operational support manager	Fleet manager
20	Heritage site	Director	Fleet manager

[2] Corresponds with code used when references are made to an interview within the manuscript.

21	NGO, social focus	Operation support manager, sustainability officer	Fleet manager
22	Furniture company	Director, fitter	Fleet manager
23	Moving company	Operations transport manager	Fleet manager
24	Vehicle leasing company	Manager low emissions vehicles and electric vehicles	Industry professional
25	Utility company	Fleet manager	Fleet manager
26	Vehicle hire company	Fleet director	Industry professional
27	Travel and tourism company	Director, operations	Fleet manager
28	NGO, sustainability focus	Electric vehicle specialist	Industry professional
29	Council services social enterprise	Transport manager, head of transformation	Fleet manager
30	Office furniture, family business	Managing director	Fleet manager
31	Telematics firm	Marketing manager	Industry professional

Table 2. Assessment of impact level

	Socio-technical trend expected to change decision-making of fleet-managers to a limited extent	**Socio-technical trend expected to change decision-making of fleet-managers to a large extent**
Socio-technical trend expected to have influence across all fleet market segments	Medium	High
Socio-technical trend expected to have influence in certain fleet market segments	Low	Medium

4. Results

4.1 UK fleet market description

Table 3 presents the number of vehicles registered to companies and commercial vehicles at the UK Department for Transport. It gives an impression of a division in between cars and other types of vehicles. Approximately, half of the vehicles are cars. The share of Light Good Vehicles (LGVs), typically vans, stands at around 34% and is growing. The total number of fleet vehicles shown in Table 3, 5.4 million or ±15% on a total number of 38 million vehicles registered in the UK as of 2017 is a likely underestimation. This is due to the registration process underlying the table[3] and to the exclusion of grey fleets from these figures.

Table 3. The number of vehicles registered to companies or commercial operators in the United Kingdom, 2016-2018 (Sources: DfT, 2020a, 2020b, 2020c).

Year	**Cars**		**Light Goods Vehicles (LGVs)**		**Heavy Goods Vehicles (HGVs)**		**Buses and coaches**		**Total**	
	No. (000s)	**% of fleet**	**No. (000s)**	**% of Fleet**	**No. (000s)**	**% of fleet**	**No. (000s)**	**% of fleet**	**No. (000s)**	**% of fleet**
2016	2,847	53.1	1,831	34.1	517.1	9.6	167.1	3.1	5,362	100
2017	2,863	52.6	1,890	34.7	523.3	9.6	164.0	3.1	5,441	100
2018	2,862	52.1	1,950	35.5	524.6	9.5	160.5	3.0	5,497	100

An estimation of the size of grey fleet is provided by BVLRA (2016), based upon data of leasing company Lex Autolease. This study notes that approximately 14 million private cars are used for business in the UK. Of these, 2.2 million (±15%) are in use in the public sector and 11.8 million in the private sector (BVRLA, 2016).

There are no exact data available on the distribution of fleets in terms of size. Experts point out that there are a small number of very large fleets such as British Gas, Royal Mail and BT. As noted by various interviewed experts, if all fleets were plotted in a graph according to their size, there would be a “very long tail” consisting of all the small and medium-sized business that own very few vehicles. In terms of ownership structure, some data is available from a company survey conducted with 3313 European fleet managers. In this survey, 45% of UK respondents indicated purchasing their vehicles, 33% used operational lease and 20% financial lease (Arval Mobility Observatory, 2018).

Fleet management refers to the variety of operations involved in the handling of a vehicle fleet over its lifetime. Typical activities include: purchasing/leasing, services (e.g., driver support; insurance; repair and maintenance), and the remarketing and reselling of the vehicle on the termination of the contract. In many organizations, fleet vehicles are the second largest expense after payroll. Despite this, the number of employees exclusively dedicated to managing vehicles have continued to decline in the past two decades, as the administration of company cars and LGVs has increasingly been outsourced to leasing companies. This trend reflects the growing challenges and complexities associated with managing and operating fleet vehicles (Venson, 2018; multiple interviewees). Within organizations which outsource most fleet responsibilities, any remaining management duties are often reallocated to staff primarily responsible for human resources, finance and procurement (Venson, 2018; Interview 4).

[3] In the UK, a distinction is made between the ‘keeper’ or registered user and the owner of a vehicle. Lease cars owned by firms but ‘kept’ by individuals do not appear in this data as company cars.

4.2 Socio-technical trends and associated drivers and barriers for V2G upscaling

4.2.1 User preferences: Diesel decline, rise in petrol and EV demand

The composition of fuels in use in the fleet market is changing, affecting the potential of V2G. Diesel is in decline (albeit far from 'dead'), and petrol and electric vehicles are on the rise. Sales of diesel cars have started to fall rapidly in the UK in the three years prior to 2020: the UK market share of diesel in new car registrations went down from 42.0% in 2017 to 22.7% in 2019. Petrol has benefitted most of the decline of diesel, as the share of petrol cars grew from 53.4% to 64.8% (SMMT, 2020a). In the LGV market, however, diesel remains overwhelmingly dominant. In December 2019, 97% of new LGV registrations were diesel (SMMT, 2020b). The number of electric vehicles is growing from a low base. The number of new EVs grew by 144% in 2019 as compared to 2018, with the share of EVs in new vehicle registrations increasing from 0.7% to 1.6% (SMMT, 2020c). However, EVs still form a very small share of the total stock of vehicles.

There are some indications that fleet managers' attitudes, awareness and expectations related to EVs are changing. A 2016 study by consultancy firm Sewells found those responsible for fleet operations were sceptical about EVs. Half of those surveyed claimed to have little or no knowledge about government grants, available EV models, charging networks or potential cost reductions associated with maintaining and operating EVs (Sewells, 2016). More recent research by consultancy BT Fleet Solutions (2018) found more UK fleet managers are trialling EVs in their fleet. Despite this, managers' views were that the models available at the time were only viable for short urban routes (BT Fleet Solutions, 2018). Changing in attitudes and expectations can also be observed in fleet managers' responses to surveys conducted by consultancy Expert Eye in 2017 and 2018 (n≈200 per annum). The share of fleet managers expecting a decline in diesel in the coming two years rose from about one third to half of those surveyed (Expert Eye, 2017, 2018). The percentage expecting an increase in fully electric vehicles doubled from twenty to forty percent. For LGVs, the expected change in fuel type was much lower, likely reflecting the performance and cost advantage of diesel over other fuel types in this sector. From the conducted interviews with fleet experts and managers, there was no clear indication whether more positive attitudes towards EV carried over to V2G. As previously observed in V2G research (Kester et al., 2018), even among insiders there was still considerable confusion regarding the possible applications and benefits of V2G.

4.2.2 Use patterns: Increasing mobility demand and changing use patterns over the day

Use patterns of fleet vehicles seem to be changing for freight and personal transport alike. The changing nature of urban freight has some potentially negative implications for a transition towards V2G technology. In recent years, considerable changes in volumes and delivery methods in freight have been occurring. A main driver of these developments is the growth in online retailing. Providing insight in the drivers behind changing fleet use patterns, Table 4 shows how online shopping continued to increase as a proportion of all retail in the UK in 2016-2018. In 2016, B2C e-commerce accounted for approximately 1.8 billion deliveries and collections out of a total of 2.7 billion packages (Braithwaite, 2017). Alongside increasing volumes, the average size of B2C parcels has also changed over the last ten years:

"when Amazon came into the marketplace it was predominantly CDs and books … but it is now a lot more clothing, shoebox size and that volume is growing. … [Previously it] was predominantly letters and an awful lot of magazines which … were a huge weight. … That doesn't happen [now as] everybody goes online. So our volume has probably [become] lighter [but] parcels [have] grown in size" (Interview 7).

The observed increases in package volume and size may result in fleet operators opting for larger vehicles. As an indication of this, Royal Mail stopped delivery using bicycles in 2014, citing larger parcel sizes as motivation (Laker, 2013). Given the lower availability of large electric vehicles, this trend could negatively affect the upscaling potential of vehicle-to-grid.

Table 4. The proportion of online sales to retail sales by type of retail, January figures, 2016-2018 (Source: ONS, 2016, 2017, 2018)

	2016	2017	2018
All retailing	13.0%	14.6%	16.5%
All food	4.4%	5.1%	5.3%
All non-food	9.7%	11.1%	12.7%
Non-store retailing	74.1%	72.9%	77.7%

In the freight segment, the expansion of smart and connected apps and services and the emergence of the sharing and gig economies have contributed to a growing demand for both same-day and out-of-hour deliveries (FTA, 2018). Consumer surveys highlight the increasing use and perceived importance of the speed of delivery. A 2016 Ipsos MORI survey among 2,153 British adults aged 16-75 years found that 29% of shoppers used same or next-day delivery at least half the time they made purchases online (Ipsos MORI, 2016). Partly driven by changing consumption patterns, the number of LGVs in the UK has grown by 59% in the period 2000-2019, with the highest growth in the segment of large vans (2,601-3,500 kg). The number of miles travelled by LGVs has increased by 56% in this period (SMMT, 2019), with the share of LGVs in all vehicle miles standing at 15% in 2019 – a number projected to grow further in the coming years (SMMT, 2019). Use patterns of LGVs are similar to cars albeit with a slightly earlier afternoon peak during weekdays and less use over weekends (DfT, 2019a). The rise in same-day and out-of-hours deliveries form a significant barrier to V2G introduction, as they increase uncertainty of when the vehicle will be used, and encourage firms to “sweat the asset” (Interview 13) of the vehicle, decreasing the time that a vehicle can be plugged into the grid.

In the personal vehicle segment, demand has increased and models are being developed to address this growth. The number of cars per household has risen over the past decades and, in 2018, 41% of UK households had one car and 35% two or more cars. Following years of decline, car trips increased by 3% in 2015-2018, while a slight reduction was observed in distance travelled (DfT,2019b). Notably, the utilization rate of personal vehicles is persistently low, and cars are estimated to be parked around 96% of the time in the UK (Bates & Leibling, 2012). Low utilization has stimulated organizations with personal car fleets to consider Mobility-as-a-Service (MaaS) platforms. These platforms include different mobility solutions (e.g. bike-sharing, public transport, pool-cars) with other complementary services such as trip planning brought together through a single digital interface (Jittrapirom et al., 2017; Hensher and Mulley, 2019). The private and public sector have traditionally relied on company cars, vehicle salary sacrifice schemes and private cars reimbursed for business use (i.e., grey fleet) to meet their organization’s mobility needs (Venson, 2018). A MaaS-informed approach, instead, seeks to analyse the ‘total cost of mobility’, which involves evaluating the best mode of transport for each journey while considering dynamic costs such as car parking. For the upscaling of V2G a shift towards a ‘total costs of mobility’ model could be beneficial as it would include the calculation of potential revenues of a variety of grid services provided by vehicles, as well as a real-time comparison with alternatives. However, an increased utilization rate of vehicles, potentially combined with on the spot booking, can be negative for V2G as it reduces plug-in time of vehicles and increases uncertainty. Additionally, MaaS is currently a ‘hyped’ phenomenon, and still at a nascent stage, with a high variety in potential implementation trajectories (Hensher and Mulley, 2019; Pangbourne et al., 2020).

4.2.3. User characteristics: Increase in number of SMEs

SMEs face various hurdles in innovation adoption. Smaller firms are more likely to have outsourced large parts of fleet management. A noticeable finding from the interviews was the limited time employees have available for fleet management. Consequently, employees charged with fleet management do not have in-depth knowledge about developments in the fleet market and related domains. Although there were no signs of active resistance to innovation, the widespread lack of absorptive capacity among SMEs is a clear barrier for upscaling of V2G, which is often perceived to be rather complex. The number of SMEs in the UK economy is rising, affecting fleet management in various sectors. In 2019, 5.9 million businesses were registered in the UK, an increase of 0.2 million (+3.5%) over 2018 (BEIS, 2020). Since 2000, the number of business has risen almost every year and this trend is expected to continue. This growth has been driven by SMEs, and particularly by a rise in the number of self-employed. In the delivery sector, which forms an important user group in the fleet market, large firms such as Hermes and Amazon are increasingly adopting a 'gig' based approach where drivers are classified as self-employed to provide more flexible working arrangements (FTA, 2018). The corresponding shift in this sector from employed to self-employed drivers has been marked. In 2016, 32% of van drivers were self-employed, whereas they accounted for nearly half of van drivers (employed=41,453; self-employed=40,673) in 2017 (FTA, 2018). These changes are also reflected in fleet statistics. Following the financial crisis of 2008 and the subsequent downturn of the UK economy, more private than company-owned vans were registered. Privately registered vans are largely employed by SMEs and self-employed sole traders (SMMT, 2019). SME-specific barriers are expected to influence the upscaling trajectory of V2G. A specific hurdle is self-employed drivers taking vehicles home at night, which reduces the potential for large-scale V2G installations in depots.

4.2.4 Technology: Rapid developments in EV, slower developments in V2G applications

EVs are improving in terms of cost competitiveness and range. A variety of plug-in hybrid (PHEVs) and battery electric vehicles (BEVs) are currently available. Batteries are responsible for most of the cost of an EV. Between 2010 and 2016, battery prices have fallen with around 75% and costs will most likely continue to fall (Curry, 2017). Many industry experts expect that the continuation of this trend in combination with growing manufacturing capabilities will lead to an increased availability of mid-priced EVs with larger battery ranges. Electric LGVs are not as widely available as electric cars. Limited range, payload restrictions and concerns about charging infrastructure form barriers for the inclusion of electric vans in fleets (Morganti and Brown, 2018). Most currently available van models are of small to medium size (<4.5 m^3), although larger vans are planned to be introduced in the UK over the next 3 years (LowCvP, 2019).

The Growth in the EV market does not automatically equate to increased uptake of V2G. While there are no fundamental technical barriers to V2G, uncertainties regarding battery degradation and efficiency remain, and communication and aggregation protocols have only partially developed (Noel et al., 2019; Kester et al. 2019). V2G is currently almost exclusively being applied in test projects (see HvA, 2018, for an overview). Most mainstream electric cars and vans lack standard V2G capability (exceptions are the Nissan Leaf and eNV200 van (Delta, 2018)). This also applies to vehicles that have been announced for market introduction in the coming 3-5 years.

4.2.5 Technology: Increasingly refined telematics systems

The application of telematics in fleet management is widespread and growing. Telematics involves the "use of computers and telecommunications to enhance the functionality, productivity and security of both vehicles and drivers" (UK Telematics Online, 2018). A survey conducted on behalf of BT Fleet Solutions (2018) with 514 fleet managers across various industries found between 76% and 91% were using telematics. The percentage was lowest in construction and facilities management, and highest in business services. Fleet managers generally use aftermarket telematics such as on-board diagnostics (OBD) plug-ins (i.e., dongles). Typical uses of telematics data are vehicle tracking and routing, driver behaviour monitoring, and vehicle condition monitoring. The implementation of telematics in fleets is not without challenges. Cost can forms a barrier for firms in low-margin sectors like manufacturing and SMEs. Driver resistance is also observed. A lack of data-analysis skills among fleet managers potentially results in data being underutilised, while only some large firms employ dedicated telematics specialists (BT Fleet Solutions, 2018; multiple Interviewees).

Telematics is playing an important role in the growth of EVs. Before organizations decide to buy or lease EVs, they often use telematics data to determine which vehicles could be suitably replaced by an EV. Criteria include daily mileage or routes. After purchase, telematics are important in monitoring the state of charge, vehicle routing while driving, managing charging events and reducing range anxiety among divers (Interviews 4 and 13). In this context, it can be expected that telematics play a facilitating role in V2G as well. Telematics-enabled charging monitoring may be even more important for upscaling V2G than for regular EVs, for example when the provision of electricity to the grid is influenced by a dynamic electricity price.

4.2.6 Infrastructure: Growth in charging infrastructure, limited V2G compatibility

EV infrastructure is expanding but availability, accessibility and costs continue to act as barriers to EV adoption in the UK. There were approximately 25,000 public charge points in the UK in August 2019, compared to 17,000 a year earlier (Zap-map, 2019). Continued growth in is highly likely over the next 3-5 years. New charge points can create capacity problems for local electricity grids. From the interviews it became clear that fleet managers wanting to operate EVs faced two interrelated issues: strict maximum requirements for the amount of power they can draw from the grid, and significant and difficult to anticipate infrastructural costs.

The increasing occurrence of problems related to EV infrastructure could provide a stimulus for V2G. V2G technology allows for a more efficient use of electricity around locations in which fleets are stationed, such as depots (Noel et al., 2018). Specifically, electricity stored in vehicle batteries can be used to power vehicles that have to be used more urgently and provide electricity to buildings onsite. Costly upgrades to grid connections consequently can be avoided or reduced.

Significantly, most existing charging infrastructure, however, does not facilitate V2G. Charging infrastructure is also generally installed for periods of at least five years, which can result in high upgrade cost to make chargers V2G-compatible, or even to being locked into infrastructure without V2G capability. Among currently competing charging standards, only Chademo supports V2G. The consortium behind the increasingly dominant CCS standard has recently launched a roadmap that indicates full V2G capability will be achieved around 2025 (CharIN, 2018).

4.2.7 Policy: Continuing support for low-emission vehicles at the national and local level

Car-related policies and taxes in the UK are complex and subject to various changes and uncertainties. A gradual increase in diesel taxes and a continuation of policies stimulating EV use are observed trends. EVs benefit from lower tax rates, with the exact rates known until the year 2025. The government also provides a grant of £3000 for the purchase of zero-emission passenger vehicles, with additional funding available for vans (DfT, 2020d). The rate of this grant is subject to review over time, dependent on developments in the EV market. The UK Government has provided £30 million of funding to develop a variety of test projects to stimulate V2G (DfT, 2018c; Innovate UK, 2017). As the electricity market regulation is amended regularly, however, fleet managers and other actors have little certainty about future expected revenues from V2G.

Fleet managers and experts expect the introduction of Low Emission Zones or Clean Air Zones (CAZs) to be an influential development in the market over the next 3 to 5 years (multiple interviewees). A CAZ is an area identified and administrated by local authorities in which targeted action is taken to improve air quality, and can be either charging or non-charging (DfT, 2017). In 2019, around 20 councils were exploring or planning Clean Air Zones (UK100, 2019). Some local authorities are already going beyond the CAZ framework. For instance, Oxford is planning a Zero-Emission Zone in which non-zero-emission vehicles (excluding some plug-in hybrids) will not be allowed.

The variety in CAZ options for local authorities makes it likely that a patchwork of different CAZs with specific rules will emerge in the coming years. This has multiple implications for EVs and V2G. There was consensus among the interviewed fleet experts that CAZs are a main driver for fleet managers to at least consider purchasing EVs. The uncertainty surrounding criteria for CAZs seems to favour EVs, as only EVs are allowed in the most stringent of zones. EVs can hence ‘future-proof’ fleets. However, in larger vehicle segments, EVs are not yet readily available. Relatedly, in various cases the introduction of CAZs is met by fierce resistance from local residents and businesses. Although CAZs thus could be a strong driver of upscaling, there is a risk that uncertainties and implementation problems might reduce public support for EVs and related innovations such as V2G.

5. Discussion

This study has identified multiple socio-technical trends with contradictory and sometimes ambiguous implications for V2G uptake. Trends and their implications for V2G upscaling potential are summarized in Table 5. In the fleet market, user preferences regarding fuel use are shifting, with diesel declining and EVs growing strongly, albeit from a low base and particularly for smaller vehicles such as cars. This trend is widely expected to continue for the coming years. It should be noted that the rise in EVs is not an automatic stimulus of V2G, as interest in EV has not yet carried over to V2G and most current EVs are not V2G compatible. Regarding use patterns of fleets, increased volumes and longer delivery hours in the freight sector work against V2G, mostly by increasing uncertainty about and decreasing overall vehicle plug-in time. Notably, the increase in self-employment in certain sectors has an impact on V2G potential as it reduces the potential for large-scale depot installations and increases resource and knowledge barriers for V2G implementation. This trend has been ongoing for the past decade and is expected to continue. Finally, electricity grid infrastructure limitations are an increasing barrier for EV deployment. This could form a stimulus for V2G, which can alleviate pressure on the grid, but there are at least two reasons for caution: currently installed charging infrastructure is not compatible with V2G, and V2G implementation in the increasingly dominant CCS standard is still in process. Given that charging infrastructure is installed for prolonged time periods (charge point lifespan estimates for councils indicate 10 years (Ruthshilling, 2017)), those two factors can ‘lock-out’ V2G from fleet management.

Table 5: Main trends in the fleet market and their implications for the upscaling potential of V2G in fleets

Category	Main ongoing trends	Implications for V2G	Level of impact on upscaling potential of V2G
User preferences	Growing interest and demand for EVs among fleet managers	More EVs potentially available for V2G, yet awareness of V2G among fleet managers still low	High
Use patterns	Increasing vehicle use times in specific sectors and organizations	Reduction of V2G potential because of reduced and increasingly uncertain plug-in times	Medium
User characteristics	Increase in number of SMEs, particularly in number of self-employed	▪ Increase in importance of SME-specific barriers to innovation adoption ▪ Less potential for large-scale V2G installations in depots	High
Technology	Improvements in EV battery technology and EV manufacturing	More EVs potentially available for V2G, but bi-directional charging capabilities still highly limited	High

	Increasing availability of telematics	Easier implementation and management of V2G in vehicles	Medium
Infrastructure	Rapid growth in EV charging infrastructure	▪ Charging infrastructure bottlenecks provide impetus for V2G ▪ Risk of lock-in without V2G, because of installation of non-compliant EV infrastructure	High
Policy	Continuous support for EV implementation, with increasing importance of Low Emission Zones	More EVs available potentially for V2G, but spatial differences in uptake more likely	High
	Uncertainty regarding influence electricity market policies on V2G	Fleet managers and other actors might lack certainty to invest in V2G-capable EVs	High

Many of our findings resonate with Demeulenaere's (2019) cautioning against overly optimistic depictions of fleets as application contexts for sustainable innovation. Reviewing the use of alternative fuel types in fleets, he identifies a variety of factors including the large diversity in organizational structure, vehicle types and refuelling infrastructures as significant challenges for innovation uptake Multiple trends identified in this study highlight additional sources of heterogeneity in fleets. The rising number of self-employed using privately owned vehicles in delivery and other sectors leads to a larger number of 'microfleets' of one or two cars. The decline of dedicated fleet managers has led to a variety of more ad-hoc arrangements and outsourcing of fleet management. The introduction of Low Emission Zones could lead to geographical fragmentation, with cleaner fleets deployed disproportionally in cities. All in all, the increasing heterogeneity in fleets and fleet management practices demands that strategies for upscaling V2G take this variation as starting point.

The main barriers for small firms, corresponding with other studies (Nesbitt and Sperling, 1998; Mennenga et al., 2018), are limited resources and capabilities for strategic thinking about fleets. The capital intensive-nature of V2G infrastructure and the limited slack resources of SMEs particularly in low-margin sectors, are additional adoption barriers. Confusion among fleet managers about the possible applications and benefits of V2G for fleet management appear to be more pronounced than other low-carbon innovations. This is related to V2G's early development stage and high uncertainty among experts and scholars about its potential uses and benefits (Kester et al. 2018). These various difficulties seem to give larger organizations with higher absorptive capacity a clear advantage in V2G implementation.

The tension between V2G's use of the idle capacity of batteries, and concepts such as MaaS which aim to increase mobility efficiency, is another finding specific to V2G. Among the wide variety of MaaS applications currently explored (Hensher and Mulley, 2019), corporate car-sharing would, if successfully applied, lead to fewer fleet vehicles which are used more efficiently. Given that V2G uses the idle capacity of parked vehicles, this would then reduce V2G potential. However, V2G could also be integrated into MaaS arrangements. For example, a different mode of transport could be recommended to a MaaS user so that a car could remain parked and connected to the grid, if this was more beneficial for economic or environmental reasons. It should be noted here that the functioning of MaaS-like models is likely to be highly dependent on specific vehicle use patterns of organizations. Moreover, although the giving out of cars as "perks" to employees with certain functions in the organization seems less common than in the early 2000s, many are likely to continue receiving them as an in-kind benefit of their job.

This research contributes to the sustainability transitions literature by providing guidance for analyses of the embedding of innovations in broader markets. Studies of market interactions are important for the identification of divers and barriers for transition in general and their upscaling phase in particular (Boon et al., 2020). Whereas previous work has focused on deliberate processes of market formation (Dewald and Truffer, 2012), this study's framework of trends in user preferences, use practices and user characteristics can be a helpful diagnostic tool to identify drivers and hurdles for transition arising from interactions between innovations and demand-side developments in existing markets. In that regard, there is no fundamental opposition between this study, which traces user-related developments and their likely effects on V2G, and constructivist perspectives that show how markets for new technologies are deliberately shaped. The current study shows markets are not stable but always changing in a variety of ways. Focusing on user dynamics can help transitions scholars to identify developments most useful to engage with in enhancing innovation upscaling.

The variety in fleet management practices between differently sized firms and effects on innovation were noticeable, and notions of absorptive capacity and slack resources might be used to develop further categorizations of organizational users in transitions. Employing a prospective angle by considering ongoing trends turned out to be useful as it allowed for a certain anticipation of drivers and barriers, without engaging in long-term scenario development. Moreover, the approach of tracing a messy variety of contradicting developments or trends, sometimes with unexpected effects, fits well with the current empirical reality of sectors studied in transitions (in which some innovations such as EVs and photovoltaics are scaling, IT use is increasing, and connections to other fields are intensifying (see Markard, 2018)).

This research has some limitations, which can be addressed in future research. First, the interaction between different trends in terms of content and timing could be studied in more detail. The sustainability transitions literature emphasizes how developments in multiple socio-technical domains can bring about 'momentum' that then drives upscaling (Suurs and Hekkert, 2009; Geels et al., 2017). This study observed that positive interaction mechanisms between trends might can also bring about negative feedback loops for certain groups of users. For example, slower uptake of telematics among SMEs due to resource constraints could delay adoption of both V2G and EVs. Second, it would be worthwhile further exploring supply-side dynamics in the fleet market, particularly given the effects that V2G could have on the fleet market in the longer term, for example related to further integration of business models related to energy and mobility.

6. Conclusions

This study set out to investigate the upscaling potential of V2G in the UK fleet market. The guiding hypothesis that changes in user preferences, use patterns and user characteristics in the fleet market influence the potential to scale up V2G adoption in vehicle fleet contexts was supported. Various trends with contradictory implications for V2G were identified. Shifting user preferences favouring EVs provide a potential, but not guaranteed driver for V2G growth, given limited compatibility of current EVs with V2G. Multiple trends in use patterns of fleets seem to reduce V2G potential, by limiting plug-in times, or making them more uncertain. The increasing number of SMEs among fleet users will complicate a transition to V2G mainly by reducing investment capacities and the possibility of depot-based installations. All in all, it can be concluded the changing market environment is highly influential in shaping the upscaling trajectory of sustainable innovations such as V2G.

Based on the trends described in the fleet market and innovation barriers and drivers, some possible strategies for V2G upscaling in fleets can be identified. The further development of telematics applications could prove useful. Telematics facilitate introduction of V2G-capable EVs by providing cost and CO_2 comparisons based on vehicle use data and can help reduce uncertainty about when vehicles are available for plug-in at a depot. Persistent problems of innovation adoption among SMEs could be addressed through innovation intermediaries or leasing firms. Such intermediary organizations can help diffuse knowledge regarding sustainable vehicles within and across sectors (Kivimaa et al., 2019). Another possibility is questioning the increase in SMEs itself. Various sectors important for the fleet market, such as logistics, are characterized by a large share of SMEs and 'gig economy' drivers operating on low profit margins. The need for more sustainable transport can be seen as an opportunity for a more fundamental reconsideration of the regulation of these sectors (Dablanc et al., 2018).

Acknowledgements

This research was funded by Innovate UK, competition programme 1705_CRD_TRANS_V2G_DEMO. We are grateful to interview participants for their time and support, and to Karla Muenzel, Johannes Kester, Paul Gambrell and delegates at the 2019 ERSS Conference in Phoenix and the 2020 IST Conference for their constructive feedback on previous versions of the manuscript.

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Supplementary Materials

Supplement 1. Fleet Expert and Fleet Manager Interview (Group 1 and 2)

1. Fleets in the UK
    - Based on your current understanding, can you provide me with an overview of the total number of fleets in the UK?
    - Which criteria would you use to segment the vehicle fleet market in the UK and why?
    - What is your estimate for the size of the various segments associated with the criteria you have identified?

2. Approaches to managing fleets in the UK
    - What are the main processes and systems involved in fleet operation and management?
    - Potential follow-up themes and questions:
        - Who is responsible for different aspects of fleet operation and management? In-house management or external? Which aspects? Why?
        - How flexible or responsive are these processes and systems?
        - What, if any, software is used in their operation and management?

3. Electric vehicles and fleets in the UK
    - In what ways might the adoption of electric vehicles and V2G services change existing processes, systems and ways of doing things?
    - How do you see the market in the UK for electric vehicles and V2G services now and in the next 5-10 years?

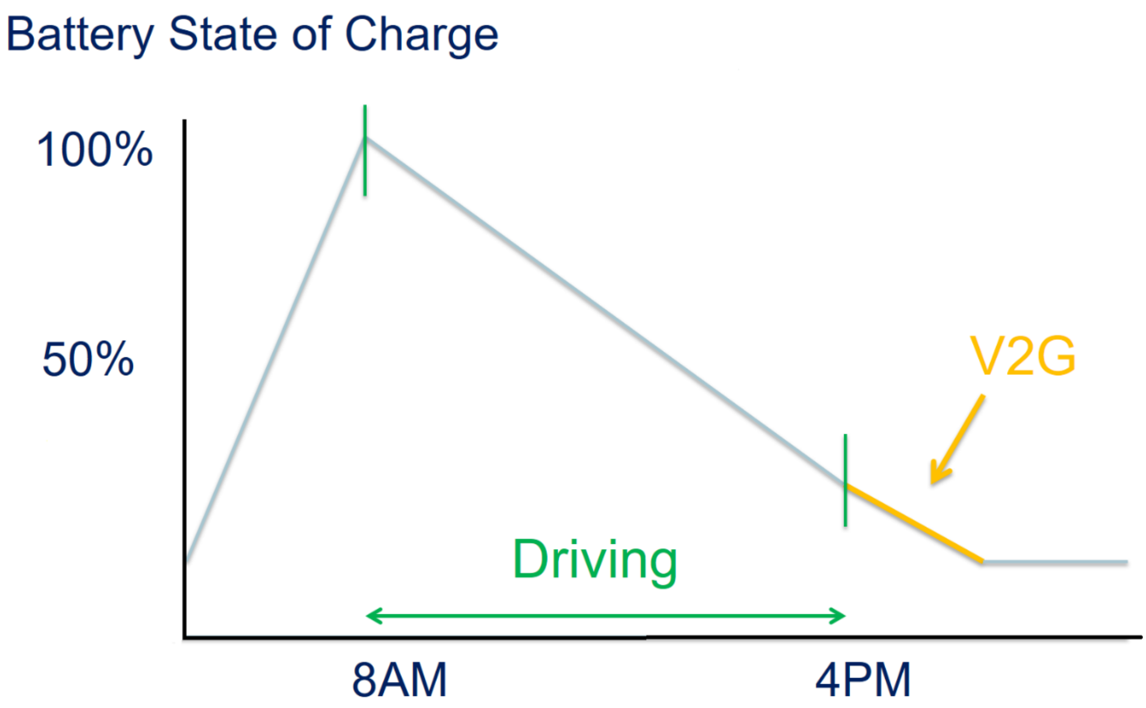
Supplement 2. Fleet Manager and Industry Professional Interview Schedule (Group 3 and 4)

1. General information about fleet
    - What is your role in your organization?
    - What is the size and composition of your organization's fleet?
    - Do you currently have any electric vehicles?

2. Vehicle-to-grid trial
    - How did your organization get involved in the trial?
    - Did you already have a look at the dashboard?
    - On the V2G online dashboard would you prefer to see savings per year or savings per mile for V2G?

3. Fleet operation, procurement and management
    - What are software or telematics systems that you use in the daily operation of your fleet?
    - Can you describe how the process of procurement of new vehicles works?
    - What are criteria on the basis of which decisions get made in vehicle procurement?
    - Where do you get you information on new vehicle purchase and fleet management?
    - Do you think that electric vehicles and vehicle-to-grid vehicles will change fleet management in the future?

4. V2G Business model scenario Exercise



- What do you think of this use of vehicle-to-grid as shown in the picture?
- What could be a motivation for you to start using V2G?
- Think again about the picture I showed you. Vehicle-to-grid carries some risk of battery degradation. The size of this risk is still unclear. When using V2G, you have to ensure as fleet manager that the vehicles are always plugged-in. As discussed, the vehicles have limited availability for out of hours for emergency drives. You could receive a financial

compensation for making your vehicles available for vehicle-to-grid. What would you see as a reasonable compensation per year? (*Break-even is fine for applying this technology/Around 100 Pound per car per year/Around 500 Pound per car per year*/*More than 1000 Pound per car per year)*

- Would it be possible to have your vehicles at the depot [one hour earlier?] (specific suggestion based on the time-patterns fleet as answered). What compensation would be needed for one car if you would do this for one month, for example next January?
- (Imagine) you have solar panels on the roof. Would you be able to store the energy generated in parked EVs during the day when the sun shines or are all vehicles driving at that point?
- In V2G, another organization will be managing the charging and discharging of your car. Who would you trust to run the vehicle-to-grid service and manage the charging and discharging of your car? Printed out on card and then ranked by interview participant *(A lease company/An energy company/A new-recent mobility service company/A large fuel company such as Shell or BP /A car manufacturer)*
- Imagine a V2G vehicle is offered to you by another company. How would you go about deciding on using the V2G vehicle or not?
- Do you see any other barriers for using V2G vehicles in your organization? Any possibilities?
- Can you think of any government measure to stimulate the uptake of V2G?

5. Clean Air Zones, Sector Trends and V2G trial

- Can you describe what are currently the two most important trends in your sector that influence fleet management?
- Are you aware of the developments around Clean Air Zones? Do you think you will be affected by them in the coming 3 years?
- Did either of the sector trends stimulate or hamper you to participate in the V2G trial?
- Are there any barriers you expect if you were to participate in the part of the V2G trial with actual vehicles?