Electric vehicle manufacturers' perceptions of the market potential for demand-side flexibility using electric vehicles in the United Kingdom[1]

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ABSTRACT

While there is extensive research on the technical potential of electric vehicles (EVs) to provide electricity system flexibility, no work has sought to understand how EV manufacturers see their role in this transition. Here we present an interview study with 11 EV manufacturers active in the UK, determining their perceptions on the market potential for demand-side flexibility using EVs. Findings indicate manufacturers view significant potential in this market, but believe time is needed (i.e. in the 2020s) for the EV market to develop before there is enough system/consumer demand for flexibility using EVs. They believe better price signals are needed, and prefer a consumer-led approach (rather than, for example, mandatory smart charging). Most manufacturers recognise they have a role in making flexibility a viable offering, but for it to succeed it needs coordination with other players, notably energy suppliers, aggregators, network operators and consumers. Governments should have a role in encouraging and brokering such partnerships. There was little evidence of concern that network constraints resulting from multiple EVs charging on the same circuit could act as a brake on sales. We identify a risk that EV growth could outpace available infrastructure and flexibility market mechanisms, leading to grid management challenges.

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1. Introduction

The energy transition and the role of electric vehicles

To meet climate change targets, countries across the world are undergoing an "energy transition", including decarbonising power generation and seeking to enable widespread electrification of both heat and transport (Ekins et al., 2013). The substantial increases in intermittent, variable generation that we have seen in the early stages of this transition are already presenting significant challenges for power system operation (Clark, 2016) and this is only set to increase as demand increases from electric heating and EVs – the latter of which is the focus of this research.

The EV market has grown rapidly in recent years, firstly through hybrid vehicles since the turn of the millennium, with manufacturers turning their attention to pure EVs in the last five to ten years. There are now over 3 million EVs on the road worldwide, an expansion of over 50% since 2016 (International Energy Agency, 2018), and the market is maturing, with Bloomberg New Energy Finance (2017b) projecting there will be 120 pure EV models on the market by 2020. Some authors predict an imminent EV 'tipping point', with falling battery costs and increased vehicle ranges making these vehicles viable for the mass-market (Frost & Guillaume, 2016). There is increasing political support across the globe as well, driven both by air quality and decarbonisation concerns. In 2017, the UK government announced a ban on the sale of petrol and diesel cars by 2040 (MacLellan & Faulconbridge, 2017) and similar measures have been announced in Norway, France, Germany and India, with China and the Netherlands signalling their attention to do the same in the near future (Al-Ghaili, 2017).

This expansion of EV capacity could however cause immediate problems for the power system, with information from trials in the UK (My Electric Avenue, 2017) showing that even small clusters of vehicles charging simultaneously could lead to network problems. Simultaneous increases in

intermittent, renewable generation further exacerbate the issues for network management, as both supply and demand become more unpredictable and vary throughout the day.

To manage this, the power systems of the future will need to change from systems typically based on large scale, centralised, non-intermittent generation, where flexibility is delivered on the supply side and demand is passive, to smarter systems where flexibility is delivered through a number of sources and the demand side is much more active. The energy system will need to utilise *demand-side flexibility* (BEIS & Ofgem, 2016) - a term that covers a wide range of activities on the demand side to reduce or shift electricity demand during peak periods (National Infrastructure Commission, 2016). The term is often used interchangeably with *demand-side response* and *demand-side management*, where the former usually refers to responses to market price signals and the latter usually refer to more wide ranging actions to reduce or shift electricity demand at peak times (Bradley et al, 2013).

EVs as a source of flexibility

The predicted growth of EVs will contribute significantly to the increased electricity demand on the system, but may also represent a tool by which to manage that demand through demand-side flexibility if the charging patterns of EVs can be correlated with the needs of the electricity system (Aunedi & Strbac, 2013). EVs are potentially well suited to demand-side flexibility, as in the long term they are likely to add a significant load to the system, have a battery with a significant capacity that can be used to store and discharge electricity when needed and typically only need charging for a relatively small proportion of the time when they are not in use (ICF International, 2016). The scale of the value that can be derived from using EVs for demand-side flexibility will depend on when the increased electricity demand will fall throughout the day, the technical capabilities of the vehicles and charging solutions to participate in demand-side flexibility and the market mechanisms that are put in place to incentivise vehicle owners to shift their consumption.

This is a nascent market, with organisations currently scoping out the value that might exist and their potential role. Large, multinational organisations such as Shell and BP, have begun to make inroads into the EV market in Europe by acquiring suppliers of charging infrastructure (Vaughan, 2018) but little progress has been made in bringing demand-side flexibility and EV propositions to market beyond small scale trials of vehicle-to-grid (V2G) technology and niche tariffs to incentivise demand-side flexibility from EV owners.

This research

The existing literature in this area (covered in Section 2) has focused on consumer attitudes towards EVs and (to some extent) these vehicles' suitability to provide demand-side flexibility, but less attention has been given to how manufacturers see their role in the future energy system and potential commercial opportunities to develop demand-side flexibility propositions with EVs.

To inform the direction of policymaking as this market develops, more research is required to understand the market potential and any barriers to realising this. EV manufacturers could be well placed to capture the value in this market, but so too could other players including aggregators, network operators and suppliers (Hall et al, 2017). This paper reports the findings of research focusing on the perspectives of EV manufacturers active in the UK market, seeking to understand their perceptions of commercial drivers for and barriers to demand-side flexibility using EVs and explore from the perspective of the manufacturer where the market value could be derived in different time horizons and with different business models. In doing so, it aims to answer the question:

What is the perception amongst electric vehicle manufacturers of the UK's market potential for demand-side flexibility using electric vehicles?

The research had three main objectives:

- To explore common themes amongst EV manufacturers' views on the potential market for demand-side flexibility and compare these across different time horizons and under different models of vehicle usage and ownership;
- To understand perceptions about the formation of the market, the value that an EV manufacturer may derive from it and potential business models for an EV manufacturer;
- To explore any commonly cited market barriers from the perspective of an EV manufacturer.

The next section briefly reviews related research in this area. The method (involving interviews with EV manufacturers active in the UK market) is described (section 3), and the findings discussed (section 4). Section 5 sets out the conclusions and implications for policymakers, academics, and industry.

2. Demand-side flexibility and EVs

This section summarises the key research on demand-side flexibility, focusing on the role that EVs play both in increasing electricity demand and providing a means (through the EV battery) by which to mitigate the stresses they place on the grid.

Drivers for demand-side flexibility – the impact of EV growth

The current and future economic case for demand-side flexibility has been clearly made through a number of modelling exercises. Studies such as Gross and Heptonstall (2017) and (Strbac et al., 2015) have examined the potential system impacts and costs of intermittent generation in the UK and found that these costs can vary hugely, with the variance largely down to the flexibility of the system. With this in mind, Sanders et al (2016) estimated the optimal levels of future flexibility technologies using a system model and found that the UK could save £17-40 billion from now to 2050 through demand-side flexibility.

A key driver of this value in demand-side flexibility is projected increases in electricity demand, largely due to electrification of heat and transport. Bloomberg New Energy Finance (2017a) estimate that global electricity consumption from EVs will rise to 1800 TWh in 2040 (from 6 TWh in 2016), and without demand-side flexibility this will mean a significant increase in peak time consumption, with a significant impact on the power system. In the UK, ICF International (2016) conducted a review of major UK EV trials to find that EV uptake could contribute to a domestic peak demand of nearly 2KW per household, which would represent a doubling in peak demand. National Grid (2017) predict that without smart charging of EVs, there will be an extra 8GW of peak demand by 2030 due to large increases in EVs throughout the next decade.

Using EVs for demand-side flexibility

There is therefore a clear case to mitigate the potential strain that EVs will put on the grid by using demand-side flexibility. If EVs can be charged 'smartly', such that their charging is optimised to take advantage of off-peak charging as much as possible, National Grid (2017) estimate that the increase in peak demand by 2030 could be as little as 3.5GW. Similarly, Brandmayr et al (2017) cite a study from Pudjianto et al (2013) which estimates that increases in EVs without changes to charging habits will result in network upgrade costs rising to £36 billion between 2010 and 2050, while using smart technology to shift EV and heat pump demand could save up to £10 billion over 40 years.

The technical capability of EVs to provide this flexibility is well evidenced in the literature, with studies such as Huang & Infield (2011) and Teng et al (2016) using UK domestic car trial data to illustrate the potential responsiveness of EVs and the flexibility benefits of these technologies. There is agreement and significant evidence that smart charging of electric vehicles is technically feasible and economically viable, although the potential degradation of the vehicle's battery life has been a hotly contested issue. Uddin et al. (2018) brought together the results of two previous papers which were at odds on this issue: Dubarry et al (2017) suggested that V2G degrades the life of the battery while

Uddin et al (2017) found that a smarter grid would make V2G economically viable and would mean battery lives do not degrade. Their 2018 study looked at areas overlap between these studies and found that while current V2G technology can degrade battery life, it can be improved and degradation can be controlled and managed using a control algorithm. V2G even has the potential to be used as a tool to extend battery lives when it is used as part of a smart system.

These technical studies have served to show that using EVs for demand-side flexibility is technically feasible and potentially economically viable. The research has not however assessed the market mechanisms for how this flexibility could be realised in practice or explored potential commercial opportunities or business models to develop the value that is modelled into a product for consumers. Hall et al (2017) have recently taken the first step towards doing this through a multi-faceted study in which they:

- conducted 21 semi-structured interviews with the automotive industry, utilities, governments and charging infrastructure providers;
- developed a set of innovative e-mobility business models for EVs ; and
- conducted a 'needs analysis' to assess how well different models satisfy the innovation needs of EVs and the system.

Their conclusions highlighted a series of barriers to these models and made a number of recommendations, including energy tariff innovation to enable tariffs that reward demand-side flexibility. While this is a welcome first step, the authors did not examine ways in which the commercial sector can engage with and adopt business models which might unlock flexibility, or explore the innovation needs of the user (though they did highlight a need to do this). They also did not consider the size of the commercial value for each of the models or who in the sector could capture that value.

The literature gap

There is a need to go beyond technical studies and conceptual business models for flexibility services with EVs to consider how these should be applied in practice, how the market could be designed to deliver flexibility and who would be well placed to capture the value in the market. There is a potential commercial opportunity for market players in this sector, and one which EV manufacturers may be well positioned to capitalise on, but more needs to be done to understand how the market could form in order to aid its development. This research explores these issues through elicitation of the views of EV manufacturers, asking where they can derive value from the market and what might need to change in the policy, regulatory, technological and consumer landscapes for the market to deliver that value.

3. Method

This section describes the interview method, including selection of the sample companies and interviewees, interview content and our approach to analysis.

The research was conducted through a set of semi-structured expert interviews, with representatives from eleven EV manufacturers active in the UK market. We selected this flexible interview method because our motivation in this research was to get detailed insight into manufacturers' perspectives, and let their priorities come to the fore. We wanted the opportunity to probe and question interviewees' assertions, something which a less interactive approach (such as a survey) would preclude. We were concerned that a less personal survey approach would present a risk of low response rates as well as providing us with only brief responses. Since there is not a large population of EV manufacturers working in the UK, and they are likely to be quite heterogeneous, we considered that any additional benefit of breadth of coverage of such an approach would be outweighed by the value of increased depth of insight enabled by semi-structured interviews.

The sample was derived through purposive sampling, a form of non-probability sampling whereby participants are selected based on the researcher's judgement as to which will be most valuable for the research (Babbie, 2001). The intention was to capture views from as many manufacturers as possible, but limited only to EV manufacturers to increase the depth of the analysis and the comparability across the sample.

The sample included manufacturers of EVs for domestic and for commercial purposes, and different vehicle types including electric cars and buses. The exact business model and commercial structure of the companies in the sample also varied, with some conducting their research and development in the UK along with their manufacturing activities, some only manufacturing in the UK and others only importing into the UK. These variances across the sample present a challenge for analysis, but also add depth to the analysis by contrasting different (but comparable) perspectives on the research question.

Identification of the right experts is critical to the success of a qualitative interview (Morgan, 2014), and this is particularly true for this research given that the subject requires technical knowledge alongside an understanding of the commercial landscape. A balance also needs to be struck between the knowledge and authority of the person to make meaningful statements (and to feel empowered to speak on behalf of their organisation), the availability of that person and the likelihood of getting them to interview (Kvale & Brinkmann, 2008).

Interviews were therefore aimed at government affairs representatives in order to strike the best balance between knowledge and accessibility. These representatives are used to interviews given their public-facing role and will have an appropriate level of seniority to answer questions on behalf of their organisation. They are also likely to be the most accessible participants for the research given the lead author’s part time role at Ofgem, the Great Britain electricity and gas markets regulator (see below, this section).

Table 1 below outlines the market focus of each of the organisations involved. In the results (4.1. - 4.3.), quotes have been tagged using the number in the left hand column of Figure 1.

Table 1: Breakdown of interviewed manufacturer by market segment.

	Domestic	*Commercial*
1	✓	✓
2	✓	✓
3	✓	
4	✓	
5	✓	✓
6	✓	
7	✓	✓
8	✓	✓
9	✓	✓
10		✓
11	✓	

Interviews lasted an hour and were conducted in person in an office setting where possible, or over the phone where not. This approach was proportionate in order to access the right experts in the timeframe allowed, given the global nature of organisations involved. The interviews began by discussing the organisation's current involvement in demand-side flexibility using EVs, before exploring their views on the potential future market. The widest definition of demand-side flexibility was used deliberately to leave the interviewee scope to provide evidence on the areas of the most relevance to them, and this was explained to the interviewees. This therefore included typical price response mechanisms, smart charging and feeding back power to the grid through vehicle-to-grid services.

This first stage of the interview was designed to allow participants to share their views without being led by our (the researchers) own priorities and expectations. However, we were also keen to hear their reactions to a number of propositions/provocations related to the research objectives:

- ***Proposition 1****: Electric vehicles are well suited to providing demand-side flexibility.*
- ***Proposition 2****: Current infrastructure and technology are not conducive to electric vehicles providing demand-side flexibility.*
- ***Proposition 3****: There is not currently a viable demand-side flexibility market proposition for electric vehicle manufacturers, but there may be in the future.*

- ***Proposition 4****: There are policy and regulatory barriers preventing demand-side flexibility using electric vehicles.*
- ***Proposition 5****: Consumer acceptance and uptake of both electric vehicles and demand-side flexibility will greatly affect the potential market for a manufacturer.*

These propositions were focused in areas known to be of interest to regulators (the lead author was an employee at Ofgem, the British gas and electricity regulator – see below, this section), and interviewees were prompted either to agree with or rebut them, and provide further explanation. Introducing these subjects was useful in promoting discussion and allowed us to capture points of particular interest to the research, albeit possibly to the exclusion of other subjects which may have arisen in the context of a less structured interview.

The interviews concluded by discussing the interviewees' key focus points for the future. Interviews were audio recorded and subsequently transcribed and coded for analysis coded using NVivo software (QSR International, n.d.). The approach to analysis of the qualitative information from the interviews was inductive and thematic (Braun & Clarke, 2006), whereby the interview data was used to generate a theory rather than looking to prove or disprove a pre-existing theory. The coding was used to generate themes, such that the themes were derived from the data and not predetermined. This approach is consistent with the exploratory nature of the work, “when existing theory or research literature on a phenomenon is limited” (Hsieh & Shannon, 2005, p1279).

The research presented a number of ethical considerations. As the insights that were sought related to the business strategies of the organisations interviewed, participants were asked not to provide any information they consider to be commercially confidential. Participants were asked to sign an informed consent form before each interview, presented alongside an information sheet explaining that the interviews were to be recorded and subsequently transcribed, with the output presented anonymously.

The lead author combines part-time study with full time employment at Ofgem (the UK gas and electricity regulator). This role has potential advantages for the research, as it could theoretically provide greater access to potential interviewees and it may well be easier to secure their involvement. However, there is a dilemma between getting participants to agree to take part and ensuring full disclosure of the terms by which the research is being conducted. It was clearly set out to the participants that this work is not being conducted through Ofgem, and it is being undertaken through the researcher's role as a student. It was also clearly explained to participants that findings of the research will not directly feed into any Ofgem work, except through the usual academic communication and engagement routes.

In considering the findings, it is important to bear in mind other contextual considerations. Interviews were mainly conducted with government affairs representatives of the manufacturers in question (although where these were not available people with other roles such as product managers and sales and marketing experts were also included – see table 1). Such individuals may or may not be experts in questions around technical capabilities of EVs, precise details of potential consumer offerings, etc. However, we think it is reasonable to work on the basis that they are very familiar with their firm's public policy and regulatory priorities, and would be expected to take the opportunity to convey them.

Given this assumption, it is useful then to consider on what basis certain subjects may or may not be raised. Focusing on reasons why certain subjects may not be raised, explanations could include:

- The subject is commercially sensitive and the interviewee did not want to signal an interest in the subject.
- The subject is not a policy priority for the manufacturer, and therefore is either not known to the interviewee or was so unimportant as to have not been viewed as worth raising.
- The subject is important to the manufacturer, but the interviewee was not asked about it and did not pro-actively raise it.

We would argue that the first two points are quite plausible, but that the third is less likely since this study was an opportunity for government affairs professionals to convey what they see as policy/regulatory priorities relating to flexibility and EVs. In this context we now consider the findings based on topics which were raised in discussion with interviewees, as well as some which were not, with particular focus on implications for policy.

4. Results and discussion

Here we present the results of our thematic analysis, taking in manufacturers' views on the importance of flexibility in the context of EVs, the potential they have to offer flexibility, and the role of manufacturers, consumers and other actors in unlocking it. We consider these results in the context of previous research, and discuss the practical implications.

4.1. Importance of flexibility

There was broad consensus that electrification is the clear direction of travel for the automotive industry, whether that be hybrid, plug-in hybrid, pure electric or fuel cell EVs. EVs form a big part of the current and future strategy of all organisations, with significant reductions in battery costs driving rapid increases in sales volumes in the last two to three years and that increase expected to continue and lead to a significant volume in the 2020s. Air quality concerns were consistently noted as a key driver for this growth.

All of the interviewees had at least some awareness of the drivers behind demand-side flexibility and its potential, but they had highly varying degrees of knowledge and experience in the area, suggesting it is probably not a top priority across EV manufacturers. Manufacturers are not expecting a widespread flexibility market to develop within the next five years and instead are expecting the market to develop in the medium-term (5-15 years), driven by rapid acceleration of EV sales in the 2020s. This is broadly consistent with published estimates, although these vary considerably. For

example, the International Monetary Fund projects EV penetration of around 30% by 2027 (Cherif, Hasanov, & Pande, 2017), while Bloomberg New Energy Finance estimate 14% of new vehicle sales in Europe will be of EVs in 2025 (Bloomberg New Energy Finance, 2018).

At this stage manufacturers have not seen any customer demand for flexibility as a product and it is not seen as an important factor (or even a factor at all) in vehicle purchasing decisions, where decisions are taken on the basis of the upfront cost and range of the vehicle, amongst other factors. Instead, organisations are involved in pilot projects and research trials with the aim of preparing the technology and market offerings to be ready when consumer demand is:

> *We need to make sure we are far enough ahead of potential increases in customer demand and interest to make sure we can offer demand-side flexibility when consumers are ready [1]*

There was a strong message from many that the potential market for demand-side flexibility using EVs is contingent upon the scale and timing of growth in EVs and supporting infrastructure, which they believe will be closely linked to decreases in the cost of battery technology. Indeed, policy concerns mostly related to support for growth of the EV market rather than policy specifically related to demand-side flexibility. Manufacturers noted:

> *You need a critical mass of electric vehicles to make a problem for the grid and a compelling business case as a result of those complications [6]*

> *It's going to be driven by conditions on the grid and the growth of renewables [4]*

It was suggested that the extent of the current stresses on the grid and price signals from variable renewable generation are not yet high enough for a market in demand-side flexibility using EVs to develop. There was interest across all interviewees in what this could provide for customers, but most are not expecting this to be a proposition for customers in the next five years and are focused instead on scoping out future opportunities and ensuring they can serve market demand when it arrives. In

fact this view looks somewhat outdated, at least in parts of the UK. Until recently very little data has been available on the extent of network constraints, especially at the distribution level – but this situation is changing. For example, the distribution network operator (DNO) Western Power Distribution (WPD) now provides a map of generation/demand headroom on its substations[2], and many show constraints. For this reason WPD along with other DNOs are actively putting out tenders for flexibility services.

Despite holding this view, many interviewees did highlight the importance of the right market signals to incentivise behaviour change and to make the most of the flexibility potential of EVs. When mass adoption of EVs creates excessive demand and strain on the grid in the long term, there is widespread agreement across many of the manufacturers that more intelligent charging solutions will be needed. There was concern amongst many manufacturers that the current market is not giving the right incentives and signals to enable a demand-side flexibility proposition for EV owners, and that tariffs are not available in the market as a result:

> *We should work on the market mechanisms that give the price signals to market users on when they should charge their vehicles. From that signal, different technologies and business cases for smart charging will emerge [6]*

> *At the moment, there is no real evidence of specific tariffs widely available to support electric vehicles [4]*

Many interviewees feel that the flexibility markets are currently complicated and hard to navigate, and that these need to be simplified in order for manufacturers or others to be able to formulate a proposition for customers:

[2] The map is available at https://www.westernpower.co.uk/our-network/network-capacity-map. Until recently (and still for many parts of the country) such detailed information on network constraints has not been publicly available.

We need to enable a clearer market that can work financially for everyone [10]

Concern was also raised by several interviewees around the potential for tariff restrictions on EVs charging at peak times. The view across the sample was that smart charging and demand-side flexibility needed to be customer-led and a customer choice (rather than mandated), and that a strategy based on rewarding customers through incentives and price signals would be most effective:

It's got to be more carrot than stick to make advantageous for an electric vehicle driver to charge at the right times rather than punishing them [3]

The view that flexibility should be consumer-led raises some issues. Studies have estimated that the grid could face problems if as few as just six EVs are charging simultaneously in close proximity (Brandmayr et al., 2017) – a plausible scenario if at first EVs are adopted in clusters (such as in areas with more environmentally conscious consumers (Kahn & Vaughn, 2009). This suggests there could be an interim period where there are not the tariffs or products in place to help manage these localised grid challenges. As well as posing a problem for grid management, this may have a knock-on effect to manufacturers if it results in any constraint on further EV uptake in an area.

4.2. Potential for flexibility

Interviewees were in consensus that EVs are well suited to demand-side flexibility, largely because they spend most of the time parked, as they are a significant load on the system and because they have the flexibility capability through the battery. There were however a number of caveats and limitations noted, for example where one manufacturer noted:

I can see the suitability in a home when you know your energy tariff, but I'm not sure yet whether or not it would be as accepted in public destinations [7]

Several interviewees noted that the suitability of EVs for demand-side flexibility will vary significantly by customer type. These interviewees believed that domestic EVs are likely to be more flexible than fleet, but opportunities could be greater with commercial vehicles as their usage is more predictable, they are naturally clustered and they could be used to directly avoid grid reinforcements. There was, however, no clear consensus on this point. Interviewees recognised that the suitability of EVs may also differ based on their location, based on network conditions and how many other EVs are connected locally. Again, it is noteworthy that these views appear to reflect a reasonably nascent consideration of the opportunities in this area, rather than considered strategic positions.

Several interviewees stated that EVs are likely to be charged overnight rather than at peak periods. In their view this is positive for the system but could limit the value that can be derived from demand-side flexibility. Some interviewees had an expectation that in the future the ownership/use of EV owners will change from early adopters (who they view as likely to be more environmentally aware) to more mainstream owners, which may mean more people charging when the grid is under stress and greater value for flexibility. For example, one manufacturer noted:

> *Their suitability could grow over time as the generation mix changes and the variety of people to whom electric vehicles are being sold changes [1]*

While monitored data on EV charging times is scarce, there is evidence that most weekday charging in fact starts at around 6pm (Quirós-Tortós, Ochoa, & Lees, 2015). This is not inconsistent with the view that much charging is likely to take place overnight (depending on the length of charge required), but also indicates that EV users are already charging at peak times and this phenomenon is not restricted to the anticipated mainstream owners.

Most organisations said that the technology is already broadly in place for demand-side flexibility using EVs, although several noted the extra costs incurred to enable vehicles to provide power back to the grid through vehicle-to-grid services. The upfront cost of the hardware needed for this is

significant, and interviewees expected customers would require a compelling return on investment to overcome this barrier. Given the average age of cars at scrappage in the UK is around 14 years (SMMT, 2017), and in the absence of retrofitted solutions, low prevalence of such technology in the fleet in coming years could have implications for vehicle-to-grid potential for some time. Some manufacturers suggested that the costs for vehicle-to-grid technology could be (or should be) mitigated through government subsidy, on the basis that the value in this market is potentially greater than the value in smart charging.

Public infrastructure provision and interoperability was cited by many as a general barrier to both growth of EVs and using these for demand-side flexibility:

The infrastructure is not there yet in the UK, but we are seeing huge investment to improve it [7]

We need charging infrastructure that everyone can pull up and plug into [5]

Many manufacturers were concerned that technological growth could get ahead of the market and available infrastructure. Several suggested a need for a government-led EV strategy, which would include plans for infrastructure development, market growth and provisions for innovation such as demand-side flexibility:

There isn't a good overarching electric vehicle strategy in the UK [9]

4.3. Role of manufacturers, consumers and other actors

All manufacturers saw that they would have a role to play in this market. Many saw the manufacturer's role and the benefit to the manufacturer in providing a lower total cost of ownership for the customer by enabling services that others in the sector would deliver:

For us, the benefit we can give the customer is a lower total cost of ownership [8]

Many suggested a clear boundary between the business case of the manufacturer and others, although it was noted it would be down to manufacturers how to scope out their role in what would be an 'open' market. Most interviewees saw a need to partner with other actors to put forward demand-side flexibility propositions (notably energy suppliers, aggregators, and network operators), although some suggested they could offer end-to-end demand-side flexibility services.

> *We could sell this to our customers, but there are several other elements that you have to put in the equation to make it work. We need to work in partnership with others [8]*

> *I don't think it's necessarily something that we would offer as a manufacturer. It's much more likely to be suppliers or network operators [4]*

There was general recognition that the typical model of manufacturing and selling vehicles is likely to change, partly as a result of electrification but also due to wider factors. The ownership model for electric cars could extend beyond the car itself to include service agreement, tariff management and charging infrastructure.

Those organisations that are considering nearer term opportunities are looking at simple smart charging solutions and providing grid services at a local level to deal with immediate grid problems, often from a defined fleet of electric vans or buses, for example.

Given the value that potentially exists in unlocking EV flexibility (see section 2), it is perhaps surprising that manufacturers appear so ready to look to partnerships rather than building their own proprietary solutions. On the other hand, for the manufacturer, this is just one part of the picture in a sector that faces revolution, with the development of autonomous cars and the ownership model for cars challenged by emerging habits in vehicle usage (Rawlinson, 2017). While vehicle manufacturers are reimagining their role away from simply manufacturing vehicles to provision of electromobility services (Hall et al., 2017), they appear not yet to be ready to branch out of their core sectors.

The general view across the manufacturers interviewed was that consumers' acceptance of demand-side flexibility is important but also achievable, as long as there is a financial incentive for the consumer to engage with the market:

> *Consumers will accept this as long as the barriers are low and there is a financially compelling reason to do it [9]*

Several suggested that targeting early adopters and the environmentally and financially conscious first could help to normalise demand-side flexibility and would mean that customers would begin to expect it as an offering. Several also said that customers should be able to play a role in the market passively by giving them a product offering that needs little engagement, with the manufacturer or another commercial entity simplifying the product to make it accessible for any customer:

> *The market will need simple offerings for passive consumers [6]*

Communication and education of consumers was consistently highlighted as a focus point to facilitate growth in the market by improving awareness and helping customers to understand and engage with demand-side flexibility.

5. Conclusions and policy implications

This article presented findings from interviews with government affairs representatives at eleven EV manufacturers active in the UK market on the potential for demand-side flexibility using EVs. The research sought to extend the existing evidence in this area, which focuses on the technical potential and suitability of EVs to provide flexibility, by examining perceptions of the commercial landscape for those in the market.

The findings indicate manufacturers view significant potential in this market, but believe more time is needed (in the 2020s) for the underlying EV market to develop before there is enough system and

consumer demand for flexibility using EVs. The current value in the market is judged by manufacturers to be too low for a viable customer proposition, indicating that the underlying system does not yet require flexibility from EVs. Perhaps for this reason, interviewees tended to be more focused on how policy could support growth of EVs in general, rather than how they might be deployed to unlock flexibility.

Where interviewees made policy suggestions relating to flexibility, it was for better price signals, and that the decision to offer flexibility should be consumer led (rather than, for example, compulsory smart charging). There was little evidence of concern that network constraints resulting from multiple EVs charging on the same circuit (Brandmayr et al., 2017) could act as a brake on sales. This suggests that strong leadership is likely to be required from policymakers if they wish to see action on EV flexibility – it is unlikely to be (vehicle) industry-led at this stage.

The research has shown that manufacturers recognise significant heterogeneity between different types and uses of EV, and between different customer segments. There was some belief that opportunities with commercial vehicles could be greater in the shorter term, but there was not consensus around this. Manufacturers are also mindful of differences between consumers in terms of how active or engaged they may wish to be in the market and how well informed they are as the market develops further and the profile of an EV owner moves to become more mainstream. The lack of clarity here suggests a need for more research to inform both manufacturers and policymakers of the likely impacts of different flexibility services in different vehicle and consumer segments.

We found some indications of an assumption on behalf of manufacturers that consumers will be content to provide flexibility if it is easy to do and the price is right. While there is evidence of consumer demand for flexibility products and services such as time of use pricing, this is highly variable and often low under opt-in circumstances (see Nicolson, Fell, & Huebner [2018] for a review). While increasingly work is considering potential for consumer participation in (and provision of) flexibility in

the EV context (e.g. Cook, Churchwell, & George, 2014; Faruqui, Hledik, Levy, & Madian, 2011; M. Nicolson, Huebner, Shipworth, & Elam, 2017), more research is needed to understand drivers of participation and what could increase it (see also Sovacool, Noel, Axsen, & Kempton [2018]). High levels of uptake should not be assumed under opt-in models.

Most manufacturers recognise that they have a role to play in turning flexibility into a viable market offering, but for it to be successful it needs coordination with other players, notably energy suppliers and aggregators, network operators and the consumer themselves. There was little evidence of manufacturers expecting to provide end-to-end solutions themselves, despite the value that could be available in this space. Government is likely to have an early role to play in encouraging and brokering such partnerships, and innovation funding such as that recently dedicated to vehicle-to-grid trials. Ruel (2018) provides evidence that this is happening. However, policymakers should also be conscious of the regulatory challenges that may emerge when sectors which have previously be regulated differently, by separate bodies, begin to blur together. Approaches to handling such transitions are already being proposed (Sandys et al., 2017).

The EV market is therefore at a critical point in its development, and this development is set to take place at a time of uncertainty and concern about the state of competition in energy markets, with the government recently announcing a review of how to deliver affordable energy and ensure clean growth (Wright, 2017). For the UK, our research suggests there is a risk that EV technology could outpace the available infrastructure and flexibility market mechanisms, leading to a situation where the grid cannot cope with the increases in EVs but the market mechanisms are not in place to help manage this increased demand. There is a need for clear and consistent policies for flexibility to support the market as it develops and enable the electrification and decarbonisation that the UK requires.

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