Article:
McKinney, T.R., Ballantyne, E.E.F. orcid.org/0000-0003-4665-0941 and Stone, D.A. orcid.org/0000-0002-5770-3917 (2025) Understanding the rural demographics need for electric vehicles. International Journal of Logistics Research and Applications. ISSN 1367-5567

https://doi.org/10.1080/13675567.2025.2475938

Taylor & Francis
Taylor & Francis Group

International Journal of Logistics Research and Applications

A Leading Journal of Supply Chain Management

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/cjol20

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To cite this article: Thomas R. McKinney, Erica E. F. Ballantyne & David A. Stone (20 Mar 2025): Understanding the rural demographics need for electric vehicles, International Journal of Logistics Research and Applications, DOI: 10.1080/13675567.2025.2475938

To link to this article: https://doi.org/10.1080/13675567.2025.2475938

Published online: 20 Mar 2025.

INTERNATIONAL JOURNAL OF LOGISTICS: RESEARCH AND APPLICATIONS
https://doi.org/10.1080/13675567.2025.2475938

Understanding the rural demographics need for electric vehicles

Thomas R. McKinney[a], Erica E. F. Ballantyne[a] and David A. Stone[b]

[a]Sheffield University Management School, University of Sheffield, Sheffield, UK; [b]Department of Electrical and Electronic Engineering, University of Sheffield, Sheffield, UK

ABSTRACT

UK Government legislation has outlined the transition from Internal Combustion Engines (ICE) to Electric Vehicles (EVs) with the most recent Ten-Point Plan detailing the ending of sales of ICE vehicles by 2030. With EVs already gaining popularity, this transition is already underway. However, past large socio-techno transitions often leave rural communities behind (e.g. Internet and mobile connectivity). Therefore, a key part of engaging with rural communities is to provide a smoother transition for these areas to EV usage. This paper examines the nuances, particularly of the EV transition in rural areas identified through a survey distributed to households within the Peak District, a large rural area of the UK. Households were invited to complete an online survey about their travel patterns, current vehicle usage, awareness, and acceptance levels of EVs, electricity tariffs and charging, and access to public transport. This paper presents the findings from this survey.

ARTICLE HISTORY
Received 22 March 2024
Accepted 2 March 2025

KEYWORDS
Electric vehicles; survey; rural travel; vehicle usage; transport

Introduction

The transport sector is one of the largest contributors to UK greenhouse gas emissions (DfT 2021). To achieve the 'net-zero' targets set by the UK Government (BEIS 2019), their latest 'Ten Point Plan' details the ending of sales for new petrol and diesel vehicles by 2030 (Energy Saving Trust 2021). Electric Vehicles (EVs) are low-emission vehicles that provide a positive contribution to this goal (Hirst 2020).

The transition from Internal Combustion Engine Vehicles (ICE) to Electric Vehicles (EVs) is already underway; however, there is a risk of rural areas falling behind. Rural communities have often been left behind during large-scale socio-techno transitions in the past, for example, Internet and Mobile Phone Connectivity (Williams et al. 2016). The UK Government's 'Road to Zero' strategy outlines this transition but also expects the transition 'to be industry and consumer led' (DfT 2018). This approach gives rise to concern, as it will only work for locations where there is a strong business case (Cooper 2018). It is also unlikely that market forces alone will lead to the installation of EV charging points in rural areas, where the customer base is significantly smaller than in urban areas, and the cost of grid connections can be very high (House of Commons 2018).

Private vehicles are crucial for rural communities, where public transportation options are limited (Better Transport 2018), and utilities and amenities are spread further apart leading to considerably greater car usage (Newman et al. 2014). Considering that 9.7 million people live in rural areas (within England alone) (DEFRA 2021), who, from 2035, will find that they are

CONTACT Erica E. F. Ballantyne e.e.ballantyne@sheffield.ac.uk Sheffield University Management School, The University of Sheffield, Conduit Road, Sheffield S10 1FL, UK

increasingly forced towards EV adoption in order to conform with government legislation banning the sale of new fossil-fuel-based vehicles. Therefore, it is imperative that these areas are considered appropriately for such changes to be successful.

This paper presents results from an online survey that has been targeted towards rural households to gather information on their vehicle usage, EV ownership, and related infrastructure such as charge points and electricity metres. Results have been analysed to highlight the nuanced perspective of the EV transition in rural areas, ensuring that these stakeholders' views are understood and integrated.

This therefore informs a broad research question to investigate 'What is the potential impact of the EV transition on rural UK communities?'. This study will then facilitate a better understanding of the adoption of EVs in rural areas, in addition to the necessary support infrastructure. This therefore benefits all stakeholders in these rural environments, in particular the rural community. This aligns with the premise of stakeholder theory, which argues that an organisation should create value for all stakeholders, not just shareholders (Freeman 2010). This paper takes a stakeholder approach to help address this concern.

For the context of the research presented in this paper, 'rural demographics' refers to users of vehicles within a rural environment, where 'A rural area is defined as having settlements of less than 10,000 people or Hub Towns, with populations between 10,000 and 30,000, which provide services and businesses for a wider rural hinterland' (UK100 2021). More specifically, with the objective of determining the vehicle usage of owners, the number of vehicles at an address, the number of people in the household, and the typical distance travelled in a given period (day).

The remainder of this paper is organised as follows: firstly, a review of relevant literature; followed by the 'Research Approach' section detailing the survey construction and data collection exercise; finally, the 'Results & Discussion' section, followed by the conclusions, limitations and future work.

Literature review

The business case for rural areas in the current climate, including lower population densities, longer journey distances, and perceived lower return on investment (ROI) for organisations and investors installing EV charging infrastructure, leaves rural communities at high risk of being 'left behind' (House of Commons 2018). This disparity uncovers a critical research gap – the need for inclusive strategies that ensure rural communities are integral to the EV transition narrative. Addressing this gap necessitates a theoretical lens that accommodates diverse interests and facilitates equitable value creation across all stakeholder groups.

There is a general lack of consideration for the EV transition in rural areas from an academic perspective, resulting in few examples of previous studies with entirely rural-focused data collection. However, some previous studies have indirectly captured rural data despite this not being the main focus of the studies. Examples of these will now be discussed, as well as studies that are more predominantly centred on urban environments. These examples therefore provide a more holistic view but still retain much that could be considered translatable to rural settings.

The importance of an inclusive approach (i.e. open communication between all stakeholders of the rural EV transition) when tackling the EV transition is highlighted by various studies (i.e. Esmene and Leyshon 2019; MICT 2016). Therefore, this study seeks to involve the rural community as an active stakeholder and participant in understanding the transition to EVs in rural areas and to facilitate a smoother shift, data collection from a sample rural area will be conducted. With this approach in mind, a survey was developed in order to capture this stakeholders viewpoints. In preparation for this, examples of previous EV studies have been reviewed and are presented below.

Grahame-Rowe et al. (2012) highlight the need for infrastructure investment to convince consumers to adopt EVs. This conclusion followed from a questionnaire conducted with 40 UK private passenger vehicle drivers at the end of a 7-day period of using an EV. This was the first UK EV trial

focused on the needs of mainstream vehicle consumers. Participants were recruited from areas including the Berkshire, Hampshire, and Surrey regions, with the survey itself including a location question that provided the option for participants to indicate the type of area from which they reside (rural, urban, or suburban). Of the 40 participants, 20 lived in a suburban environment, 13 in urban and 7 in rural locations (Grahame-Rowe et al. 2012). Whilst this only forms a very small survey sample, the results suggest the prioritisation of personal mobility outweighs environmental benefits (Grahame-Rowe et al. 2012), a finding also corroborated by Bailey, Miele, and Axsen (2015) and Skippon and Garwood (2011).

Further, the participants of Grahame-Rowe et al. (2012) study also recognised the environmental benefits and 'righteousness' of operating an EV; however, participants had multiple complaints. These included the adaptation in driving style necessary for operating an EV, lack of confidence in the vehicle, and range anxiety. However, this study is over 10 years old, and since then, EV technology has moved forward considerably in all these aspects. Therefore, it would be beneficial to conduct a similar questionnaire today to allow direct comparison between the views as they change over time.

Newman et al. (2014) challenged the widely held belief that EVs are ideally suited for urban settings, suggesting instead that they could be equally, if not more, effective in suburban and rural areas. The authors also highlight the typically longer commuting distances in these areas (30-80 km round trips), which they argue align better with the discharge-recharge cycle of EV batteries. However, this implies that after a typical day's travel, an EV might have limited capacity for additional trips without recharging, potentially prohibiting further immediate travel. In addition, the longer average travel distances in rural settings, as opposed to urban ones, could lead to a more significant cost benefit of using an EV over an ICE vehicle.

Additionally, rural properties often have larger available space, including the prevalence of designated off-street private parking (e.g. driveway, garage, carport, etc.) (Newman et al. 2014). This allows for a greater possibility of home charge points to be installed, which reduces the dependence of the rural driver on public charge points. Further, for rural EV drivers without access to off-street home charging, the dispersed nature of amenities (e.g. shops and utilities), leads to available charge points at public locations becoming more useful and helps to improve the charge point business case (Newman et al. 2014). Jones et al. (2020) also highlight not only the lack of focus on the challenges faced by the rural community regarding the EV transition but also note the possible suitability of EVs in these settings. Jones et al. (2020) assessed the impact of rurally based businesses adopting EVs for their transportation and found them to be a suitable substitute for their existing ICE vehicles, provided there is the required infrastructure and technical support available.

Hardman et al. (2018) conducted a large-scale literature review of studies investigating infrastructure needs to support EV integration, which included a brief overview of multiple questionnaire surveys that have been deployed in the past. From the review conducted by Hardman et al. (2018), Dunckley and Tal (2016) found most American EV drivers only charge their vehicles at home, with some charging at both home and work. Dunckley and Tal (2016) surveyed over 4,000 EV owners across 11 American states to investigate the attitudes and perceptions of EV owners with regard to the roles of electricity companies and grid operators in the EV transition. The only criterion for participation in the study was ownership of an EV. However, there are no published statistics on the participants' locations (i.e. rural or urban). Although from the demographics collected, 98% reported living in detached houses (Dunckley and Tal 2016), supporting earlier studies that rural locations more often lead to the availability of off-street parking and charging facilities.

Carley et al. (2013) also surveyed 2302 consumers from over 21 major US cities pertaining to their intent to purchase an EV, with the main focus being range anxiety. With this study concentrating on consumers in major urban areas only, it inherently carries a bias towards a demographic likely less concerned about driving range when compared to rural consumers. Consequently, this bias may lead to an underestimation of the genuine concerns regarding EV driving range. The

Carley et al. (2013) survey was conducted through the autumn of 2011 before EV marketing campaigns became prevalent. This enabled Carley et al. (2013) to capture true preconceived consumer notions of EV performance at the time. Carley et al. (2013) report that the perceived disadvantages of EVs are significant deterrents that need to be overcome; however, the relevance to today's market is dubious given the significant advancements in EV technology over the last decade. Regardless of this, any residual range anxiety issues may be addressed via public policy and investments. For example, this could be alleviated through the installation of more public charge points. A course of action that is currently a priority of the UK Government (DfT 2023).

As detailed, there are many examples of conducted studies that have aided the understanding of the EV transition. However, there are few examples of studies that focus on rural areas alone, attempting to capture any nuances these environments pose towards the transition. This paper attempts to address this gap within the literature, so as to facilitate rural-focused technical analysis and investigations centred around the EV transition in these areas.

Research approach

In order to study the potential impact of the EV transition on rural UK communities, a large-scale online survey was designed to provide context around understanding rural household perspectives on EV ownership and subsequent EV charging requirements. A survey was selected as the most appropriate approach for data collection over a large geographical area, whilst also ensuring a large set of specific data could be gathered quickly, consistently and anonymously from a large number of households during a specific time period (Bryman and Bell 2015; Saunders, Lewis, and Thornhill 2016). This has the additional advantage of avoiding interviewer bias which is more likely to occur through interviews and focus groups (*ibid*).

Survey construction

The research presented in this paper was based on a survey developed using Google Forms. This offered a user-friendly approach, from both its design and participant perspectives, and enabled the easy export of responses to Microsoft Excel, for data analysis. Prior to the commencement of data collection, ethics approval from the university administered through the department of the first author was obtained.

It is important to note that a distinctive aspect of this survey was that it was targeted from a household perspective, rather than that of an individual. The survey consisted of 18 questions, in 5 sections related to aspects of the EV transition and rural areas. These sections were as follows: (1) Demographic, (2) Your Cars and Travel, (3) Electric Vehicles, (4) Charging and (5) Electricity Tariffs.

The first section, 'Demographic', recorded general participant information including the general location of the respondent, thus confirming whether or not they reside in a rural location; in addition to the number of people and their ages residing at the property.

The second section, 'Your Cars and Travel', was incorporated to determine car availability and usage for each household. From a technical standpoint, this data is vital to understanding the requirements that rural individuals have for their vehicles. Previous work conducted by the authors examined the impact of EVs in rural areas, and a prerequisite for this was the development of a travel demand model (TDM) (McKinney, Ballantyne, and Stone 2023). This TDM simulated how each vehicle in a small village, Bradbourne (highlighted in Figure 1), travelled over the course of a week. The outcomes of this survey supported the validation of this model and its results. However, the presentation of the models results and their validation are outside the scope of this paper and will not be discussed further.

The 'Electric Vehicles' section was used to understand not just awareness of EVs and the transition to EVs within the rural community, but also to determine the participants acceptance of this

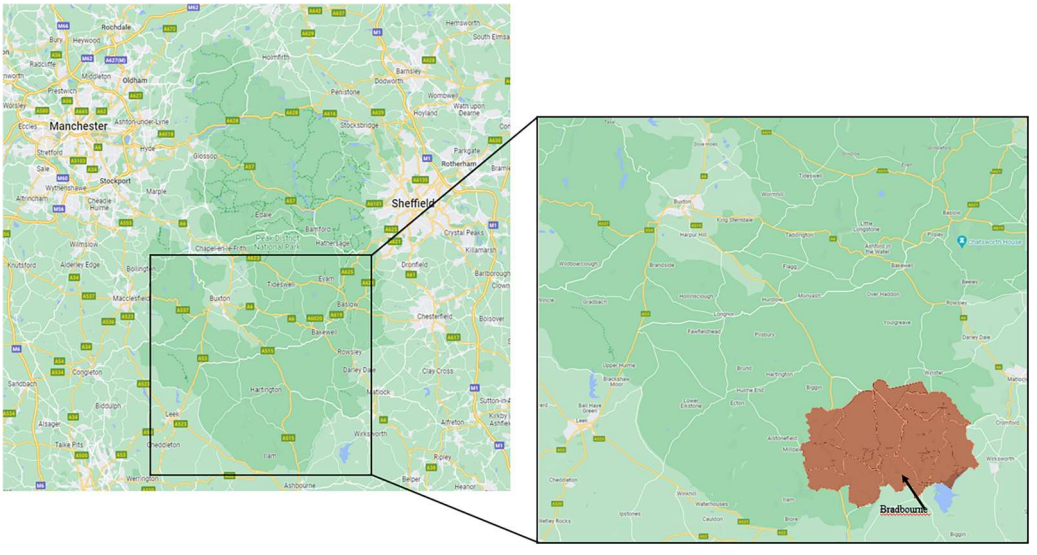

Figure 1. Initial distribution area (area includes that highlighted).

transition. Additionally, questions related to local public transport were also included to identify potential alternative means of transport and accessibility available to the participant. These questions were devised to capture opinions on the EV transition, and by extension, highlight any issues the participants foresee, so that they may be understood.

The following section, 'Charging', provided an opportunity to investigate charge point allocation and capabilities for rural households in terms of vehicle parking, the anticipated number of chargers that individuals would desire, and where they envisage charging their EVs. These questions were framed to be answered regardless of current EV ownership status and therefore invited participants to contemplate a future scenario whereby they did have an EV.

The final section, 'Electricity Tariff' was included to understand associated technical issues, such as EV-specific electricity tariffs and metres. This section also enabled insight into their adaptability for change, change that could maximise EV potential and reduce running costs.

The survey concluded with the option for participants to receive a 'results report' upon the survey's completion. This report not only included various summary results from the survey but also provided information pertaining to the EV transition itself and the various technologies highlighted in the survey. The results report sent to participants also served to inform the rural community about the EV transition, so that they themselves may become a more prominent stakeholder in the future.

Survey distribution

With the focus of this data collection on rural communities and ensuring that the EV transition does not result in life becoming more difficult for them, potential participants were required to meet a single criterion – that they live in a rural area. To be clear, the definition of 'rural' used to identify the target participants for the survey is related to the National Travel Survey 2021 (DfT 2022), where the average annual mileage in urban city and town areas is 2383 miles, compared to that of rural town and fringe areas (3208 miles). Therefore, this study defines a rural area as being any area where the residents typically travelled over 3000 miles per year on average.

A flyer was developed to advertise the survey around a predetermined rural area of interest – the Peak District, UK. The flyer had a QR code and website address, with which individuals who chose

to volunteer and participate in the research would be able to access the Google Form survey. Across an already harder-to-reach community, this may have incurred some limitations due to accessibility and technology. Individuals who may lack technological know-how, or internet access altogether (more likely in rural areas), may result in achieving a lower response rate than 'in-person' survey data collection approaches. However, the wide geographic coverage for the flyer distribution partially helped to address this issue.

Multiple distribution methods were employed over a period of 9 months, with the total data collection stage lasting 11 months. Utilising services such as Royal Mail's Door-to-Door Campaign service, local parish councils, hand delivery and contacting local schools in the area resulted in flyers being distributed to households in the areas of interest. Distribution methods were also staggered throughout the total time period of data collection. This was because of periodically increasing the focus area to try and capture a larger data set. Initially, efforts were focused solely on the village of Bradbourne and some additional surrounding villages; the areas highlighted in Figure 1.

Following initially low uptake levels, the decision was made to increase the area of survey distribution. Based on local census output areas (ONS 2023), additional parish councils and school districts in the surrounding area of Bradbourne were contacted, as well as utilising Royal Mail's Door-to-Door service to deliver almost 12,000 flyers. The final area from which the data was collected is shown in Figure 2.

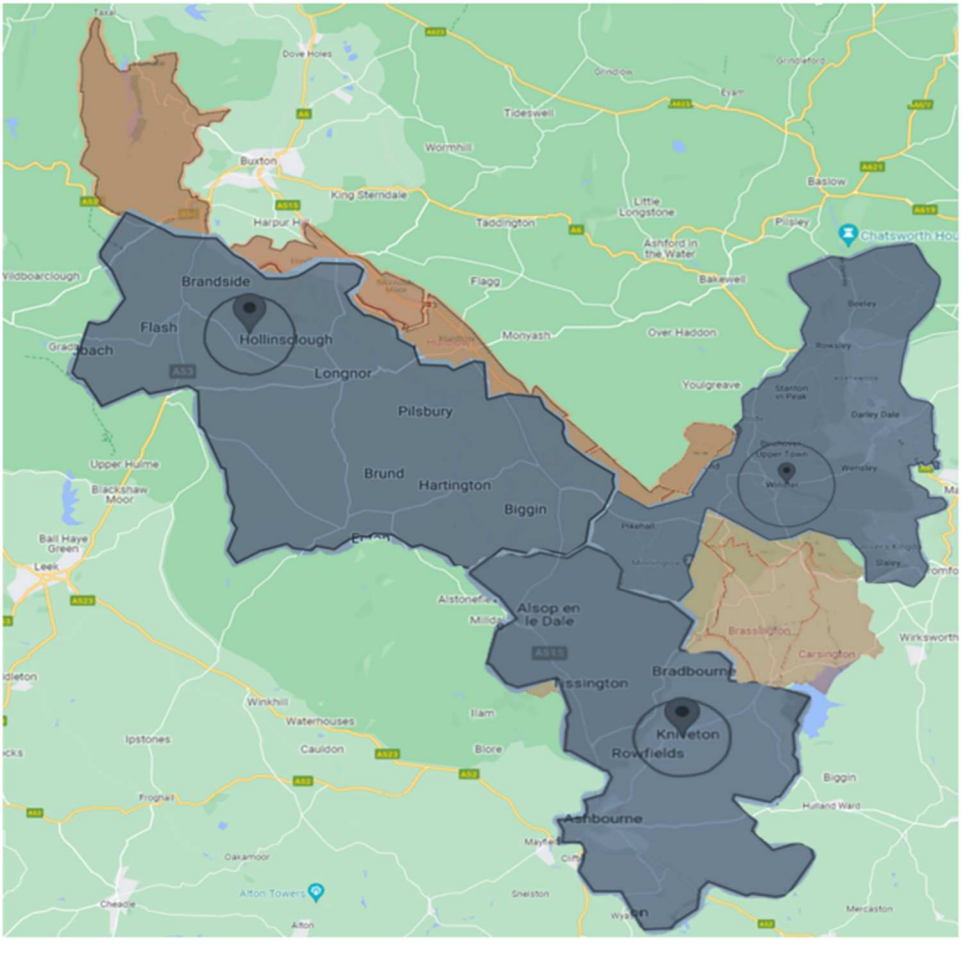

Figure 2. Royal mail batches (dark areas).

To note, the inclusion of the Royal Mail's Door-to-Door service, in particular the postcode area which serves Bradbourne (DE6 1) also extended far past the boundaries of the Peak District and into a much more populated area – the large town of Ashbourne. However, as discussed previously, the 'Demographic' section of the survey allows the identification of the participants' local area.

Results & discussion

Over 12,000 flyers were distributed, over an 11-month period, to households across the Peak District, from which 192 responses, representing 192 households were received. This captured data corresponded to over 500 individuals and 376 vehicles, the results of which will now be presented and discussed. Data from the survey will henceforth be referred to as 'Data Collection' in figure legends. The timeline for responses can be seen in Figure 3, including indications of when large advertising and distribution efforts occurred.

With data collection taking place over an 11-month time period, data was captured at multiple instances throughout the year. This includes bank holidays, school holidays, differing months of the year, and by extension, weather conditions. These are all factors that will impact responses to various questions, such as vehicle usage, which for example is very different during summer months compared to winter months. Although attempts were made to instruct participants to provide an average estimate when answering such questions, it is important to note that this may form an underlying bias.

No personally identifiable information was recorded as part of this data collection stage. The highest level of detail requested from participants was the area of residence, so as to allow for geographical analysis of results. This required participants to select their closest settlement from a list provided. Figure 4 plots the location of all 192 household responses as a heat map. It is important to note, as highlighted in Figure 4, that the data collected from this survey included responses from the town of Ashbourne. Ashbourne is a far more heavily populated area, concurrent with a more urban environment which may skew the results presented from this survey.

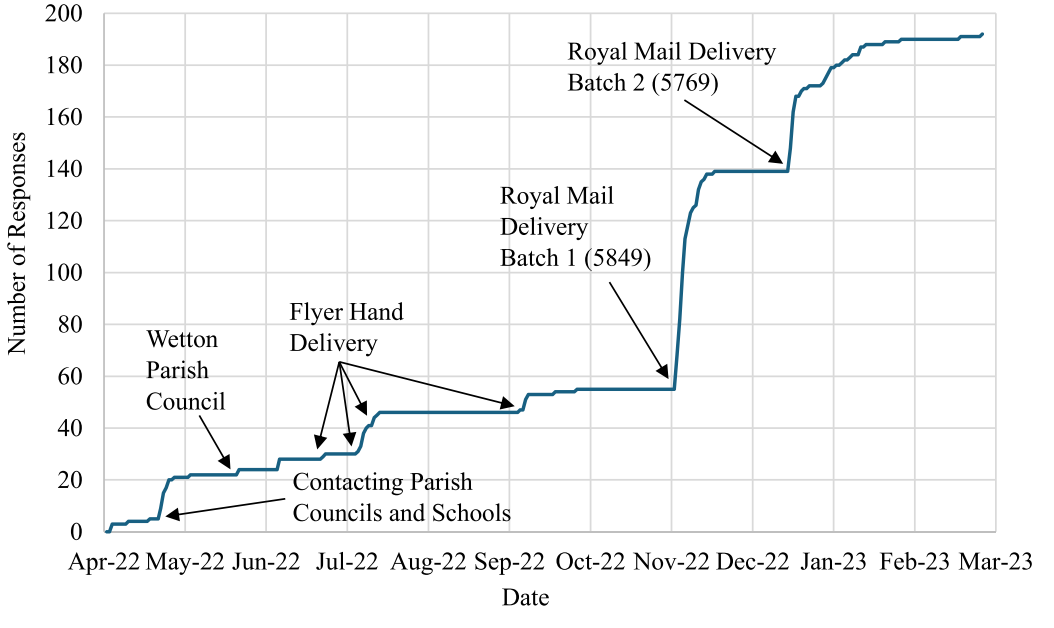

Figure 3. Timeline for responses.

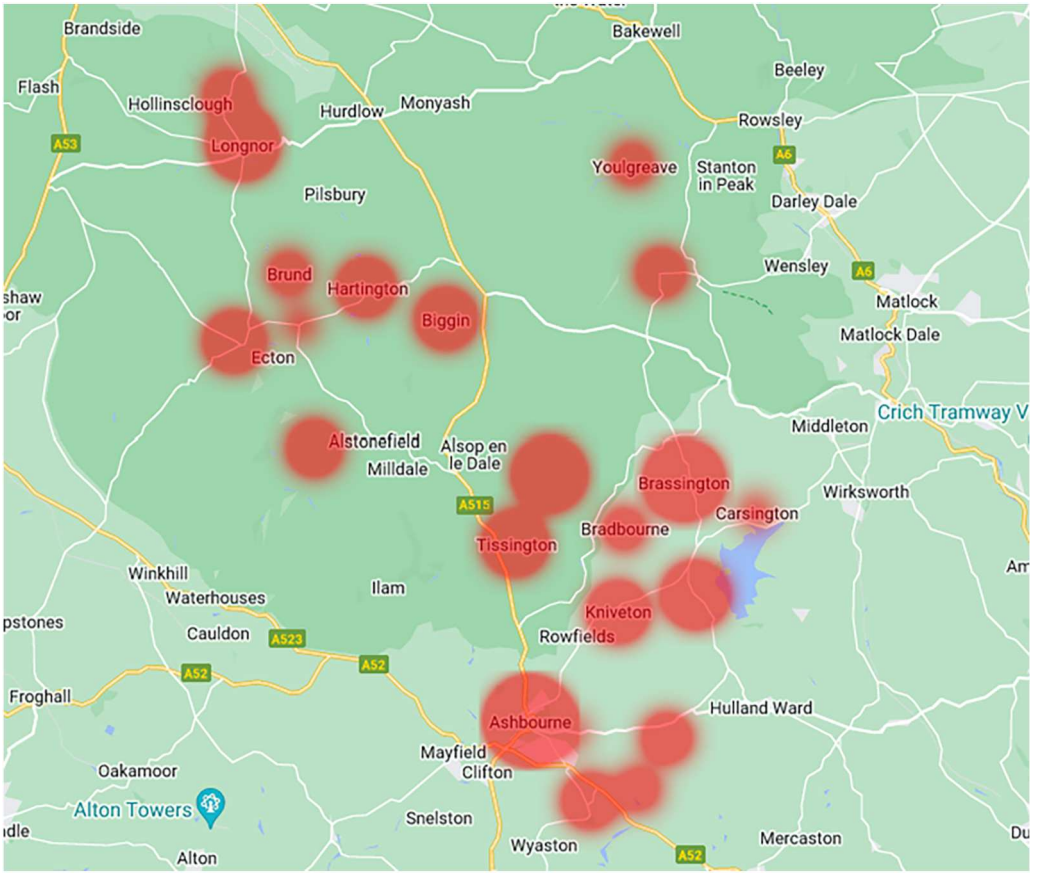

Figure 4. Heat map.

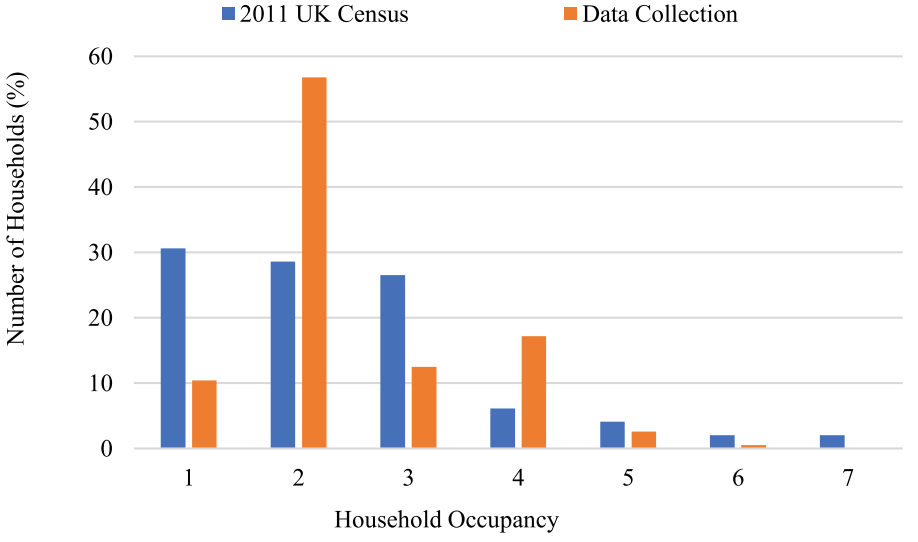

Figure 5. Household occupancy.

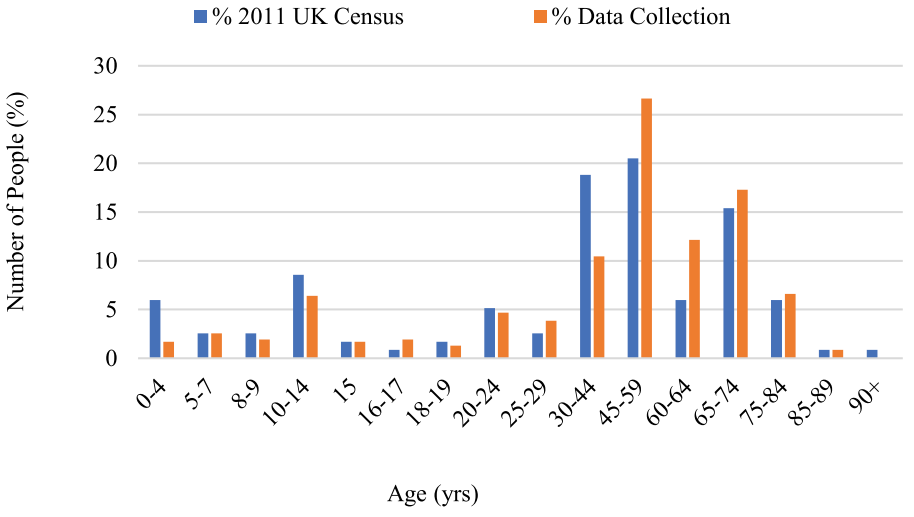

Figure 6. Age of respondents.

Figure 5 presents the distribution of household occupancy across the responses, whilst Figure 6 indicates the age profile of all 500 individuals (by percentage) captured across the 192 responses. Data from the 2011 UK Census (the most recent available UK census data), pertaining to Bradbourne specifically, have also been included (UK Data Service 2011) for comparison in Figures 5 and 6.

As shown the data collected in Figure 5 is in line with that collected by the 2011 UK Census, validating its usability for real-life deductions. Additionally, the high level of similarity for the age profile of the area, shown in Figure 6, indicates that there has been little change in this community's age profile over the last 12 years. This highlights the possibility of considering other aspects of the UK census which would still be applicable for use today, even though the data is 12 years old.

An effort was also made to investigate the age profiles of the households that already have an EV. Calculations included everyone within the household, regardless of ability to drive and own a vehicle. For all 192 households who participated in the survey, the average household age was 52.6 years. The average age of a household with an existing EV was 52.3 years. This suggests that age has very little influence on the determining factor for purchasing an EV. This is in line with reports from the Office for Low Emission Vehicles, which found that most private EV owners are currently middle-aged, male, well-educated, affluent individuals (OLEV 2015). However, conclusions on gender and education cannot be drawn from this survey, as these factors were not asked. Although these findings by the OLEV (2015) are over 8 years old, and present-day data collection suggests no change, efforts are ongoing to improve the uptake of EVs for the wider community. Recent data also suggests more than half of motorists aged 16–49 years say they are likely to switch to all-electric vehicles within the next decade (ONS 2021), which supports the results of this survey.

Across the 192 households that responded, 376 vehicles were owned, averaging out to 1.99 vehicles per household. The full distribution can be seen in Figure 7. Of these 192 households, 33 had EVs already, corresponding to a total of 38 individual EVs. The average number of vehicles per household increased to 2.12 when solely considering these households with EVs. This is not surprising as EV households are much more likely to be multi-vehicle households. These results highlight the current perception that EVs are deemed a secondary vehicle, with the need for a primary vehicle to be reliable and thus petrol or diesel. Although households are adopting EVs, only 7 households (3.6% of total responding households) surveyed had an EV as their only vehicle.

A crucial part of assessing the feasibility of EVs in rural areas is understanding the impact they will have on local grid infrastructure. This impact will be largely determined by the charging profiles

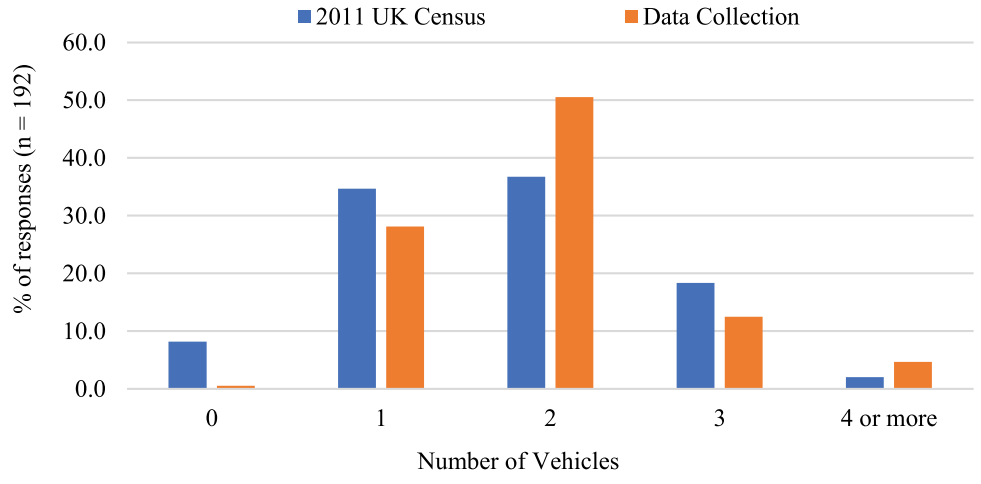

Figure 7. Number of vehicles per household.

of each vehicle, and cumulatively, their aggregation together from the perspective of the grid. Therefore, this survey sought to understand when cars are available throughout the day for home recharging events. Figures 8 and 9 display the results of this investigation for both the average weekday and weekend, respectively. Both indicate the suitability for overnight charging, a behaviour currently being heavily anticipated and pushed by grid operators, via EV energy tariffs.

From the 'Electric Vehicles' section, over 91% of respondents indicated that they are aware of the EV transition; however, this only translated into 19.3% of households anticipating their next vehicle to be an electric one (see Figure 10).

In contrast, 37% of participants responded that it would be 'Very Unlikely' that their next car would be an EV. This indicates a reluctance towards EV uptake in rural areas. Price, range anxiety and distrust of the technology all rank highly as barriers to EV adoption (Berkeley et al. 2017; Steinhilber, Wells, and Thankappan 2013; Tiwari, Aditjandra, and Dissanayake 2020); however, it is also prudent to note that the rural population is an aging population, even more so than their urban counterparts (DEFRA 2021). For this reason, and due to simply lacking the need for a new vehicle in the future, respondents may not anticipate purchasing another vehicle, regardless of its fuel type.

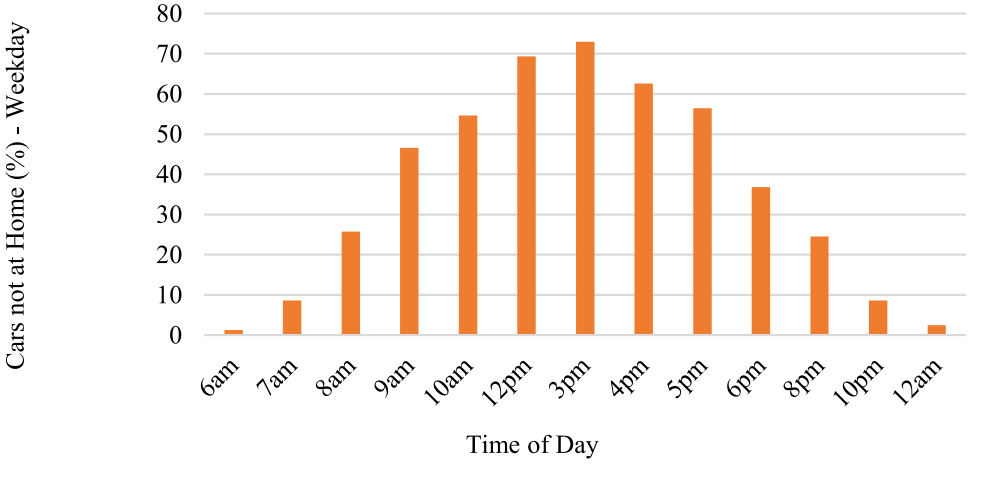

Figure 8. Cars not at home on weekdays (Mon–Fri).

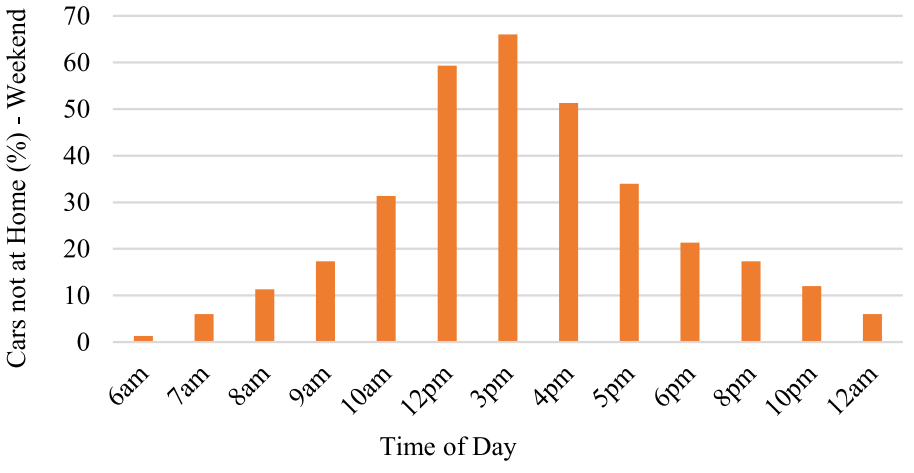

Figure 9. Cars not at home on weekend (Sat—Sun).

Distrust of the technology also encapsulates distrust of its capabilities, multiple individuals from the survey voiced concerns regarding EV towing capacities and the impact of towing on battery life, as well as weather and temperature conditions. Both of these can be more severe in rural areas due to a lack of infrastructure, for example for clearing roads during heavy snowfall. This is then no surprise given that 37% reported that it would be 'Very Unlikely' that their next vehicle would be an EV. However, when it came to replacing current vehicles with EVs, 56% reported that they do intend to, with a further 27% indicating that they will attempt to downsize to fewer vehicles per household (see Figure 11). This may be due to distrust of the technology, reducing costs associated with vehicle ownership, or a conscious attempt to reduce their environmental impact through the reduction in the number of vehicles they own. However, it is very much apparent that everyone in rural areas requires their own private vehicle as 96% report a lack of local public transport, concurrent with the report from Better Transport (2018). This is in-keeping with UK statistics which show much higher levels of household car ownership (Better Transport 2018), and the number of driver's licences (Newman et al. 2014), in rural areas.

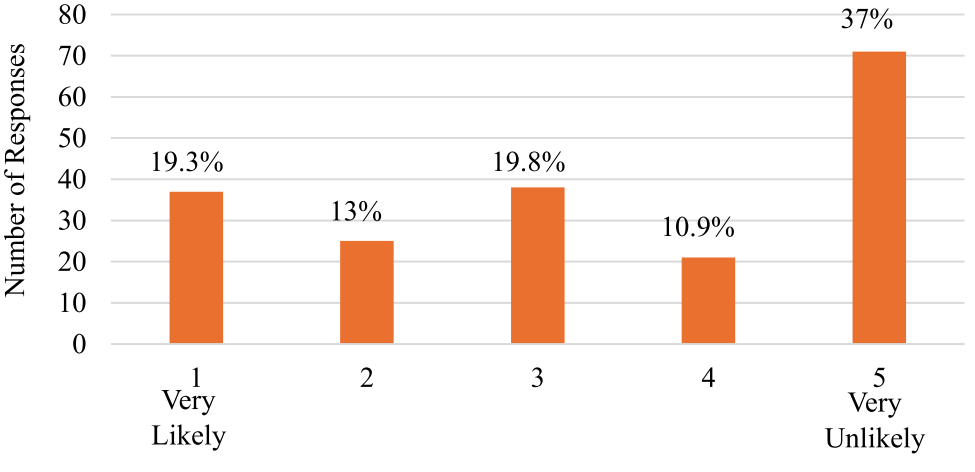

Figure 10. Likelihood of next vehicle being electric.

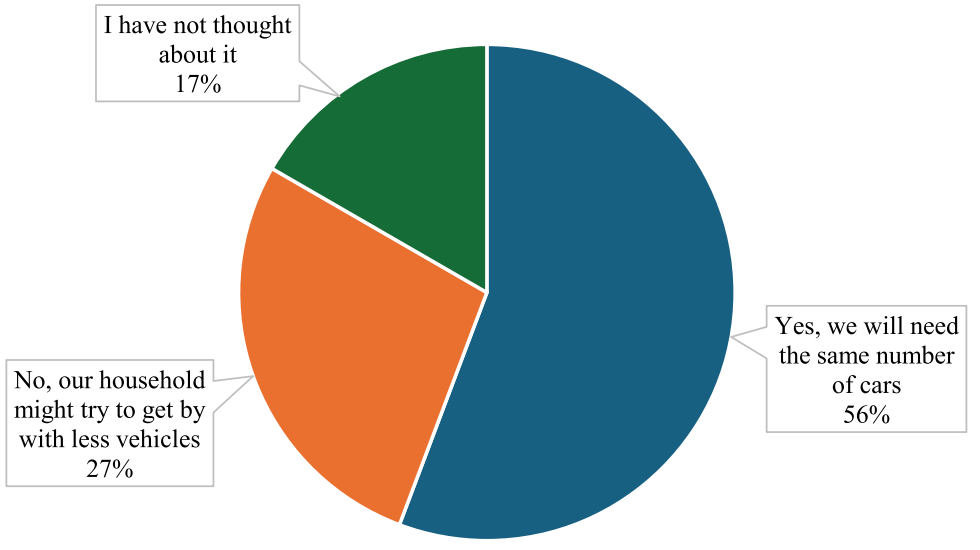

Figure 11. Intentions to replace current vehicles with EVs.

With the understanding of the perception towards EVs in the rural community, the survey sought to unearth the opportunities for EVs in this environment. A large benefit of integrating EVs in rural areas is the greater amount of space or land available at properties, particularly suitable space to accommodate home charging (Newman et al. 2014). To confirm this, respondents were asked about available parking facilities at their homes, the results can be seen in Figure 12.

As shown in Figure 12, very few households require on-road parking or have private car parking spaces situated away from their houses. Where parking is not available 'at home', and on-street parking is used, this may hinder EV ownership, due to the inability to install a home charge point. Private parking solutions on the other hand, such as a garage or driveway are much more common in rural areas and are ideal for EV charging. Over 67% of respondents indicated that they are likely to charge their EVs at home. This is in keeping with statistics published in previous literature, where Hardman et al. (2018) for example, showed that 50-80% of all charging events occur at home.

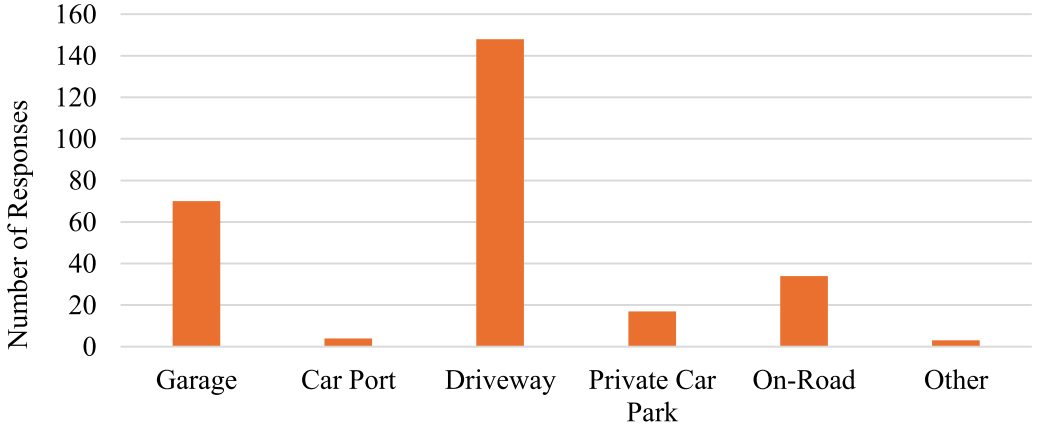

Figure 12. Available parking facilities at home.

The survey then sought to ask how many charge points the respondents envisaged installing. In reality, typical UK households would be physically limited to two home charge points, assuming both are 7 kW, due to the 100A fused electricity grid supply incomer typical of a UK domestic dwelling. This raises concerns for a household with a large number of vehicles that expects to install multiple chargers. Figure 13 shows the number of home chargers that respondents envisaged installing (orange), with the number of vehicles owned by each household for comparison (blue). The data presented here is solely for the households who expect to replace all their vehicles with EVs in the future, first illustrated in Figure 11.

As shown by Figure 13, survey responses show that households generally opt for fewer chargers than the number of vehicles they own. There is some indication of a lack of knowledge with regards to home charge points with 11% responding with 'I'm not sure', but more importantly, this question was used to uncover the individual consumer expectations. Only one household, out of the 192 that responded, owns 3 vehicles and also anticipates installing 3 home charge points, an unrealistic possibility due to infrastructure limitations as previously discussed, but further investigation would be required at those properties to be sure.

To investigate public charging opinions, the survey enquired as to which public areas would provide likely EV charging locations that the participants would utilise. The results are shown in Figure 14.

Figure 14 shows that all public areas are of high interest amongst the rural community for charging EVs, apart from 'School'. This is most likely explained due to school being a largely pick-up/drop-off event, rather than an area one expects to spend a significant amount of time at unless for instance school was a participant's workplace.

The final section of the survey sought to understand the electricity metres and tariffs at the respondents' homes. These are highly entwined factors for the EV transition. The types of electricity metres reported in this survey are shown in Table 1 below.

EV-tailored electricity tariffs are a relatively new product offered by a growing number of electricity companies, which follow, more often than not, a similar pricing structure to economy electricity tariffs. These tariffs provide cheaper electricity rates during the early hours (typically midnight to 6 am) to encourage EV charging to occur during these times of naturally lower

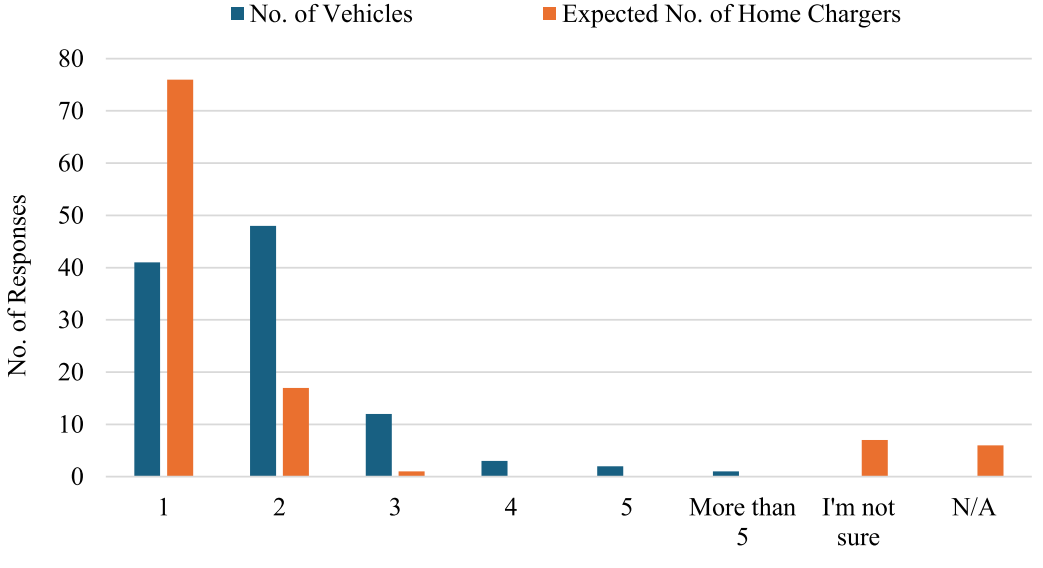

Figure 13. Number of home charge points (orange) and number of vehicles owned (blue).

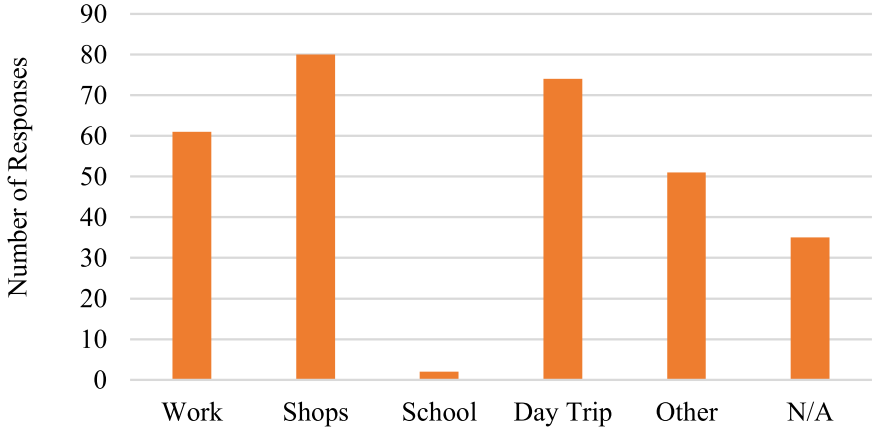

Figure 14. Public areas likely to charge at.

Table 1. Responses for what type of electricity metre households have installed.

Electricity meter	Number of responses (%)
Smart	38
Standard	28
Variable rate (Economy 7 or Economy 10)	19
Digital	10
Dial	2
Prepayment	2
Other	1

electricity demand. When asked about the awareness of these tariffs, 64% of respondents were unaware of their existence. The full results can be seen below in Figure 15.

For households to qualify for EV-tailored tariffs, in most cases, require the installation of a home electricity smart metre. From the 192 households, 46% reported that they were open to having a different electricity metre installed, with a further 33% answering 'maybe'. The remainder reported

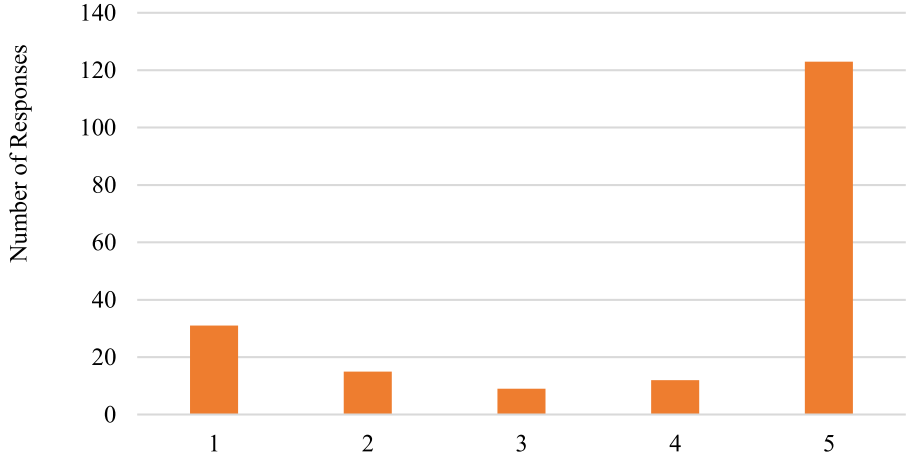

Figure 15. Awareness of EV-tailored household electricity tariffs.

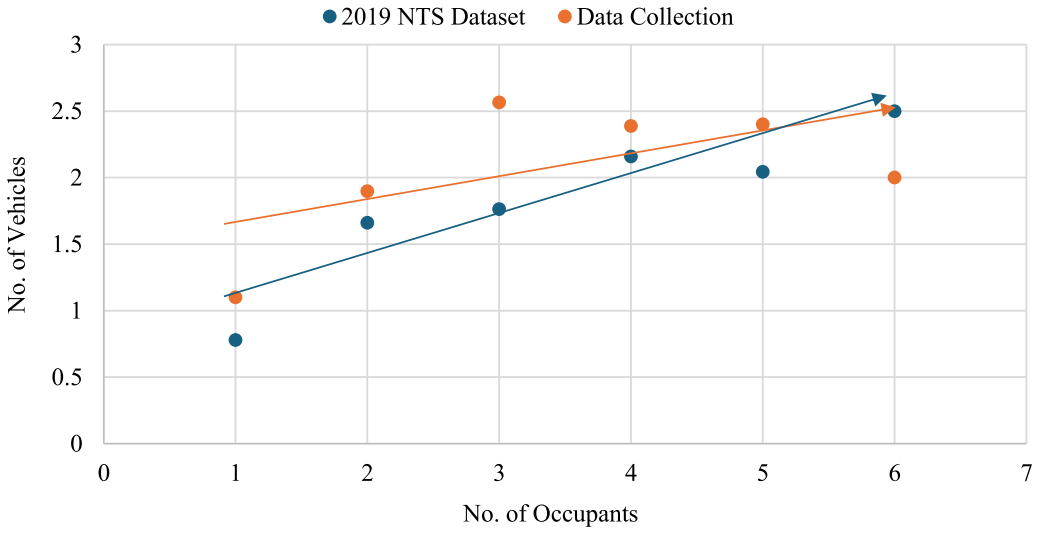

Figure 16. Comparison of household occupancies against the number of vehicles available.

'No'. However, this population of households unwilling to change may comprise, in part, of households that already have smart metres installed.

To further compare the results of this data collection with previous example datasets, Figure 16 presents the combination of household occupancy and the number of vehicles from the survey and the 2019 NTS data.

Again, as highlighted previously, it is worth noting the applicability of the NTS dataset given it is over 10 years old. However, Figure 16 does indicate a general increase, across each occupancy category, with the exception of 6-person households. This is to be expected due to the increase in car ownership levels over the last 10 years (GOV.UK 2022). Since the survey data collection results reported here are drawn from a relatively small sample, only 192 households in comparison to the 7,000 (2.74%) who take part in the NTS, some statistically insignificant results are to be expected. For example, only one household with 6 occupants was captured by the survey and thus this point in Figure 16 cannot be deemed reliable.

Conclusion

This paper presents the results from an online survey developed to investigate rural car usage, opinions on EVs and awareness of EV-related technologies and legislation amongst and applied to rural communities. This survey, as distinct from previous research, concentrated purely on the rural demographic in the UK. Engaging the rural community in relation to the EV transition gave this previously neglected stakeholder a voice for their concerns.

The survey was targeted at rural areas, specifically within the Peak District, UK. Results show that individuals in rural areas are open to new technologies and are considering the impact of the EV transition on their vehicle driving requirements. However, the participants raised some warranted concerns, vis-à-vis price, range, and applicability to their rural lifestyles. This survey highlights how imperative it is for rural households to access their own private vehicles, and given current UK legislation, they will have to consider converting to EVs at some point in the future.

Rural areas, however, offer many possibilities, including the fact that they often have access to private parking, usually off-street. This allows for much easier home charging scenarios compared to their urban counterparts and the issues faced in urban areas around access to off-street parking

and EV charging infrastructure. To date, the survey evidenced that there is already some early adoption of EVs in rural areas, however, this remains largely confined to the multi-vehicle households that took part in the survey.

Results from the survey indicate that awareness is still quite low regarding technologies that support the EV transition (i.e. charge points and EV-specific electricity tariffs). Nevertheless, results from the survey presented in this paper provide meaningful data for researchers to utilise in their investigations around EVs in rural areas. The findings are crucial to the practical implementation of future feasibility studies for EVs in rural areas, aiding the real-world transition that has already started. There are multiple implications for policymakers (i.e. around future requirements for EV charging infrastructure that considers rural locations), electrical grid planners (i.e. knowledge of anticipated demand on existing substations), as well as the consumers (the focus stakeholders in this paper) themselves (i.e. implications of their choices with regards purchasing/adopting an EV).

Research limitations and future work

Throughout the paper, the authors have attempted to highlight limitations to their survey and results, which are summarised as follows. The survey was limited to online responses only, which potentially excludes a proportion of rural residents who may not have reliable internet access, or be computer literate, from responding (Saunders, Lewis, and Thornhill 2016). In order to address this, the survey would require a longer data collection period to facilitate a paper-based postal response to be incorporated alongside the online method. Further, the survey was targeted for responses on a household level, and whilst this was seen as an advantage in that it avoids potential duplication of information from some households, it does rely on the one respondent completing the survey to provide a view that reflects the household's EV charging aspirations. Additionally, as the survey targeted both existing and potential future EV owners/drivers, it relied on those without an EV to imagine how they would likely behave if they owned one. The decision was taken to target this group of potential participants as only focusing on existing EV owners/drivers would have likely resulted in a much lower response rate and less meaningful results. Participants were also asked to respond to various questions about their vehicle usage throughout the year, and whilst they were instructed to provide average estimates it is likely that there will have been some bias resulting from the time of year they completed the survey. Finally, the research focused on recruiting participants who lived in the rural area of the Peak District, UK. It is recognised, however, that the results from this area may differ from other rural areas elsewhere in the UK.

To address some of the aforementioned limitations, the study could be expanded beyond the Peak District to other rural areas, allowing for comparisons beyond the current area of study. There is also potential for the study to be replicated in rural areas outside of the UK to provide greater insight on an international level. Additionally, it is recognised that this study utilises data from the 2011 UK Census to validate the results of the survey for household occupancy and the age of respondents to ensure the results of the survey were representative. Future studies could use more recent census data for validation as they become available.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Engineering and Physical Sciences Research Council [grant number EP/W005883/1] and the University of Sheffield Energy Institute.

Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, supporting data are not available.

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