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Analysing the usage and evidencing the importance of fast chargers for the adoption of battery electric vehicles

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ABSTRACT

An appropriate charging infrastructure is one of the key aspects needed to support the mass adoption of battery electric vehicles (BEVs), and it is suggested that publically available fast chargers could play a key role in this infrastructure. As fast charging is a relatively new technology, very little research is conducted on the topic using real world datasets, and it is of utmost importance to measure actual usage of this technology and provide evidence on its importance to properly inform infrastructure planning. 90,000 fast charge events collected from the first large-scale roll-outs and evaluation projects of fast charging infrastructure in the UK and the US and 12,700 driving days collected from 35 BEVs in the UK were analysed. Using multiple regression analysis, we examined the relationship between daily driving distance and standard and fast charging and demonstrated that fast chargers are more influential. Fast chargers enabled using BEVs on journeys above their single-charge range that would have been impractical using standard chargers. Fast chargers could help overcome perceived and actual range barriers, making BEVs more attractive to future users. At current BEV market share, there is a vital need for policy support to accelerate the development of fast charge networks.

1. Introduction

The transport sector is responsible globally for approximately one quarter of the total energy-related greenhouse gas emissions, with over 70% of these emissions attributed to road transport. To reduce transport related emissions, sustainable mobility plans of many governments worldwide include the need for a substantial shift towards the use of ultra-low carbon emission vehicles such as battery electric vehicles (BEVs) (IEA, 2016; Sims, 2014). For instance, the Paris Declaration on Electro-Mobility and Climate Change calls for the global deployment of 100 million electric cars across all market segments by 2030 (IEA, 2016; UNFCCC, 2015). However, recent (2015) electric car stock figures have only reached 1.26 million[1] cars globally (IEA, 2016) indicating the need for a substantial market growth. The low market share of BEVs is explained by several barriers to adoption such as high purchasing cost compared to an equivalent liquid-fuel vehicle, limited driving range and the lack of an appropriate charging infrastructure. Policies are implemented in many countries to increase the attractiveness of EVs and potentially their adoption rates (Sierzchula et al., 2014; Silvia and Krause, 2016). These policy mechanisms include providing financial incentives such as purchase subsidies and non-financial incentives such as access to bus lanes, free or dedicated parking spots; raising awareness on EVs; and supporting the development of EV charging infrastructure (Coffman et al., 2017; Egbue and Long, 2012; IEA, 2013; Langbroek et al., 2016; Steinhilber et al., 2013).

Recent studies assessed the impact of policy mechanisms on EV adoption. One important finding is that policy interventions may yield different impacts across different groups of people (for example, early adopters versus mainstream consumers), indicating the need for a targeted intervention approach (Langbroek et al., 2016; Silvia and Krause, 2016). In addition, Langbroek et al. (2016) found that access to bus lanes and free parking are an efficient alternative to expensive subsidies; however, these kind of incentives must be in place temporarily to avoid crowding (e.g. many cars in the bus lane) that can make these policies less attractive and could also cause unwanted side effects (e.g. encourage driving instead of using public transport). Moreover, the authors emphasised the importance of informative interventions that could encourage more people to consider an EV, such as helping people differentiate between their perceived and actual travel patterns.

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[1] 740,000 Battery Electric Cars.

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Similarly, Silvia and Krause (2016) recognised the importance of increasing awareness on EVs; moreover, they found that policy interventions perform considerably better when implemented synergistically rather than in isolation. An awareness-related policy strategy is described by Matthews et al. (2017); the authors analysed data collected by trained mystery shoppers and demonstrated the importance for policy makers to recognise the influential role market intermediaries such as car dealerships have in encouraging the adoption of BEVs. An example of an awareness campaign is the new national Go Ultra Low (GUL) campaign, a joint collaboration between the UK government and vehicle stakeholders. GUL aims to increase purchase consideration of EVs by helping potential users understand the benefits, cost savings and capabilities of available EV models on the market (Go Ultra Low, 2017). While many studies found that the presence of a public charging infrastructure is positively correlated with EV adoption rates, it is important to note that the direction of causality is not clear (Coffman et al., 2017; Mersky et al., 2016; Sierzchula et al., 2014). Coffman et al. (2017) reviewed recent studies assessing factors affecting EV adoption and found that public charging infrastructure is an important factor associated with EV uptake. Specifically, Sierzchula et al. (2014) examined the relationship between several socio-economic factors and 30 national EV market shares for 2012 and found that charging infrastructure was most strongly related to EV adoption. Looking at the country with the highest market share of EVs, Mersky et al. (2016) investigated the effects of several incentives on per capita EV sales in Norway and found that pricing incentives and increased access to charging stations may be the best policies to increase EV sales.

A public network of fast[2] chargers is argued to be a key component of an overall BEV charging infrastructure (Cruz-Zambrano et al., 2013; Jochem et al., 2016; Schroeder and Traber, 2012). Indeed, Nilsson and Nykvist (2016) investigated the near term interventions needed to enable a BEV breakthrough over the next 15 years in the EU and recognised that the availability of public fast charging is an important signal for consumers and it will support BEV growth. Unlike conventional slow charging stations that take hours to recharge a vehicle, current 50 kW fast charging stations can recharge a BEV from an empty battery to about 80% of full state of charge (SoC) in 20–30 min (DBT, 2013). Fast charging is a relatively new technology that barely existed for public use before 2013 (IEA, 2016) and it is of utmost importance to measure the usage of this technology, understand individuals' behaviour, and provide actual evidence on the significance of this infrastructure. This can appropriately inform the expansion and planning of the BEV charging infrastructure and inform subsequent studies on the topic.

Using assumptions instead of real world behaviour datasets, some studies assessed the business models for fast charging infrastructure to guide prospective investment. Profiling charging demand is critical in evaluating the profitability of BEV fast charging infrastructure business (Schroeder and Traber, 2012) and yet because of the lack of real-world data, assumptions had to be used when assessing the business case for this technology (Madina et al., 2016; Parasto Jabbari and Don MacKenzie, 2016; Pierre Ducharme and Catherine Kargas, 2016; Schroeder and Traber, 2012).

Similarly, some studies used assumptions instead of real BEV charging behaviour data to investigate the impact of fast charging on the electricity grid. In particular, these studies assumed that all BEV charging takes place on fast chargers and did not consider that BEVs can be easily charged at home for most car owners (Jakobsson et al., 2016). One study adapted the arrival time distribution of conventional vehicles at petrol filling stations to determine a typical arrival time distribution of BEVs at the fast chargers; this study found that fast chargers would affect the quality of power supply (e.g. voltage dip, flicker) and actions such as deploying energy storage solutions need to be taken in order to avoid these quality issues (Yunus et al., 2011). Another study found that fast charging has the potential to quickly overload local distribution equipment at peak times (Etezadi-Amoli et al., 2010) and even cause failure in lines and transformers unless the size and location of fast chargers are modified to avoid these impacts (Sadeghi-Barzani et al., 2014).

Using real world datasets, one study investigated the impact of the availability of fast charging on people's assessment of electromobility and found that the participants' attitudes towards BEVs improved when they used a fast charger. While the results indicated the importance of such an infrastructure in encouraging the uptake of BEVs, they were based on an experiment that exposed 62 participants who don't own a BEV to a fast charge event (Gebauer et al., 2016). Morrissey et al. (2016) analysed charging infrastructure data for the whole of Ireland including 11,000 fast charge events from 83 fast chargers. An interesting finding from the Irish study is that the mean energy consumption for fast chargers at car parks was 7.27 kWh per charge event which is similar to the mean recorded for standard public car park chargers at 6.93 kWh. While Morrissey et al. (2016) provided a preview of how BEV drivers are using fast chargers, their work did not investigate if fast chargers have an impact on driving behaviour.

This paper has two objectives. The first objective is to measure the real world usage of fast chargers by analysing over 90,000 fast charge events collected from the first large-scale roll-outs and evaluation projects of fast charging infrastructure to date in both the UK and the US. Similar trends from two distinct geographical locations were identified. This could indicate the widespread applicability of the results which may be transferable as lessons learnt to other geographic locations and assist in the rollout of future infrastructure. In addition, the findings based on real world datasets can inform theoretical assumptions used on fast charging and assist in more robust findings of subsequent studies on topics such as economic feasibility of fast charge infrastructure and impact on the electricity networks.

The second objective is to explore the impact of fast chargers on driving behaviour, specifically on driving distance, in order to evidence the importance of fast chargers. This was done by analysing 18,000 charge events from all types of charging infrastructure and 67,000 trips collected from data loggers installed in 35 BEVs that accessed and used fast chargers.

Following the introduction, Section 2 presents the datasets and methods used for the analysis, Section 3 presents the results of the analysis of the actual usage of fast chargers specifically time of use, duration and energy transferred during fast charge events. Using a multiple linear regression, Section 4 explores the influence of fast charging on daily driving distance. Finally, the discussion on the importance of fast chargers is presented in Section 5 and the conclusion and policy implications are presented in Section 6.

2. Data collection and methods

In this paper, we use three sources of data relating to fast charge infrastructure and BEVs. One dataset is collected from a network of fast chargers in the UK, a second dataset is collected from a number of BEVs in the UK that had access and used this network of fast chargers. Finally, a third dataset is collected from a network of fast chargers in the US. These datasets and the analysis methods are described below in more details.

2.1. Fast charge infrastructure data collection (UK and US)

2.1.1. UK fast charge infrastructure

Over 30,000 fast charge events were collected from 51 fast chargers (50 kW) over a period of 17 month between July 2014 and November 2015 in the UK. The fast chargers are part of the Rapid Charge Network

[2] Terminology varies by location; it is called "fast" charging in the US, "rapid" charging in the UK and Europe, and "quick" charging in Japan.