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Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour

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HIGHLIGHTS

- Electric vehicle users prefer to charge at home in the evening at peak demand times.
- Incentivisation will be necessary to encourage home charging at other times.
- Fast charging most likely to become commercially viable in short to medium term.
- Priority should be given to strategic network location of fast chargers.
- Of public charge point locations, car park locations were favoured by EV users.

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ABSTRACT

There has been a concentrated effort by European countries to increase the share of electric vehicles (EVs) and an important factor in the rollout of the associated infrastructure is an understanding of the charging behaviours of existing EV users in terms of location of charging, the quantity of energy they require, charge duration, and their preferred mode of charging. Data were available on the usage of charging infrastructure for the entire island of Ireland since the rollout of infrastructure began. This study provides an extensive analysis of this charge event data for public charging infrastructure, including data from fast charging infrastructure, and additionally a limited quantity of household data. For the household data available, it was found that EV users prefer to carry out the majority of their charging at home in the evening during the period of highest demand on the electrical grid indicating that incentivisation may be required to shift charging away from this peak grid demand period. Car park locations were the most popular location for public charging amongst EV users, and fast chargers recorded the highest usage frequencies, indicating that public fast charging infrastructure is most likely to become commercially viable in the short- to medium-term.

1. Introduction

Many European countries have made considerable efforts to increase the share of electrification in the transport sector in recent years. This can primarily be attributed to numerous concerns regarding the current state of the transport sectors in European countries. In Ireland in 2013, the transport sector was responsible for the largest share of primary energy demand (33%), the largest share of final energy consumption (40%), and the largest share of energy-related CO_2 emissions (35%); furthermore, energy use in the transport sector in Ireland is 97.5% dependent on oil products, all of which are imported, costing an estimated €3.5 billion (SEAI, 2014).

Numerous European countries have seen large growth in the share of electrification in their respective transport sectors as a result of various strategies targeting the consumer sector; in particular, Norway has seen a very large growth in EVs due to the aggressive approach undertaken in EV deployment (Assum, et al., 2014). In Ireland, a number of incentives have been offered to assist in stimulating growth in the electric vehicle (EV) population, such as a grant towards the purchase price of an EV, exemption from vehicle registration tax (VRT), and free home charge point installation (SEAI, 2015). Additionally, the Electricity Supply Board (ESB), Ireland's largest energy provider, has a central role in the deployment of a nationwide charging infrastructure including many fast charging stations (ESB, 2015).

As a result, Ireland has achieved an increase in the share of EVs in the general vehicle population, although it has been slower than expected – the initial target of 250,000 EVs by 2020 has since been revised to 50,000 EVs by 2020 (SEAI, 2014). The Central Statistics

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Office (CSO), the government body responsible for compiling Irish official statistics, states that whilst 51 EVs were licensed in 2013, a further 238 EVs were licensed in 2014, an increase of over 300%; in addition, 140 EVs were licensed in January and February of 2015, compared to 65 within the same period in 2014 and 13 in that time period in 2013 (CSO, 2015). Due to this increase in EVs, it is of utmost importance to provide a public charging infrastructure that adequately caters to the needs of all EV users.

Key to the rollout of a successful charging infrastructure initiative is the understanding of the charging behaviours of EV users in terms of when they charge, how much energy they consume, how long they charge for, and their choice of charging infrastructure type. Several studies and projects have been devised to evaluate the usage of charging infrastructure. Robinson et al. (2013) analysed the Switch EV trials in the north east of England, focusing on various charge point use cases and their effects on CO_2 emissions. An analysis of public charging infrastructure located in Amsterdam is undertaken in van den Hoed et al. (2013). The results from the Western Australian Electric Vehicle Trial are presented in Speidel and Bräunl (2014). Other charging infrastructure projects include Green eMotion (Green eMotion, 2015), CIVITAS (CIVITAS, 2015), ELCIDIS (ELCIDIS, 2015), and the Victorian Electric Vehicle Trial (State Government of Victoria, 2013). Additionally, it has been stated that the availability of public charging infrastructure is essential to guarantee the success of the widespread adoption of EVs (City of Westminster, 2009).

Furthermore, fast chargers are increasingly being considered as a practical and efficient method to ease the concerns of long charging durations. In 2012, there were approximately 4200 fast charging stations sold globally and by 2020 it is anticipated that there will be approximately 460,000 installed worldwide (Jerram and Gartner, 2012). A growing number of studies are focusing on the different aspects of fast chargers, such as the optimal spacing and sizing of fast charging stations (Sadeghi-Barzani et al., 2014), the economics of fast charging infrastructure (Schroeder and Traber, 2012), and the implementation of fast charging stations into the electrical grid (Sbordone et al., 2015; Dharmakeerthi et al., 2014). However, as a relatively new technology, there is very little research conducted thus far into fast chargers using real fast charging data.

As such, the primary aim of this paper is to conduct an extensive analysis of charge event data recorded by data loggers located in charge points located throughout Ireland and Northern Ireland. In order to ensure that the charging needs of a growing EV population are catered for, and in order to choose the optimal charging infrastructure rollout plan in terms of economic and practical effectiveness, an understanding of the charging behaviours of EV users at a variety of charge point types is essential. Analyses are conducted on the timings of charge events and the energy consumptions and durations of charge events to determine the effects of charging behaviours on the electrical grid. In addition, the usage statistics of various charge point use cases are examined in an evaluation of which types of charge points are used most frequently. Policy recommendations will be advised based on the outcome of the charging infrastructure analysis. The analysis encompasses fast charging data as well as standard charging data.

2. Charging infrastructure and data collection

2.1. Monitored charge points

A total of 711 charge points were monitored during the analysis period (although there are many more installed within Ireland); of these charge points, 83 are fast chargers. Fast charge points have an input/output nominal power of either 43 kW or 50 kW, delivering the charge through direct current (DC) and through three-phase electric power. Forty two of the fast chargers are located in the Republic of Ireland, with an additional 13 located in Northern Ireland as part of the ESB's aim of installing the first cross-border fast charging network (ESB, 2013); GPS coordinates were not available for the remaining 28 fast chargers. The fast chargers are primarily located in service stations along Ireland's motorways, with additional fast chargers situated in public car parks.

609 of the charge points that were monitored within the dataset are standard charge points, with the remaining 19 charge points of unknown type (these charge points returned very few data, and these data were not included in the analysis). The standard charge points that returned data have an input/output nominal power of 22 kW and they deliver the charge through alternating current (AC) and three-phase electric power. 346 of the charge points are located in the Republic of Ireland, and an additional 191 are located in Northern Ireland; the remaining 72 standard charge points did not return GPS coordinates. The charge points within Northern Ireland are owned by Northern Ireland Electricity (NIE), which is a subsidiary of the ESB Group. Fig. 1 displays the locations of the charge points monitored during the analysis period, with the fast charge points displayed on the left and the standard charge points presented on the right.

In addition to dividing the charge points into standard and fast charge point types, the charge points are further segregated into varying use cases. This may be beneficial in order to assess the contrasting behaviours at different charge point locations, which can also assist electromobility stakeholders because as the share of EVs grows, the demand for public charging infrastructure will also grow, and therefore this can indicate the ideal places at which to situate future public charging infrastructure. The charge point use cases are as follows: “Car Park” represents charge points located in either a shopping centre car park or within any car park located in a village or town. This is in contrast to “On-Street”, which specifically denotes charge points located at on-street parking locations. “On-Street [ESB]” refers to on-street charge points located outside the ESB headquarters. The “Multi-Modal” charge points are those located in areas where individuals leave their vehicle and use an alternative form of transport, and are divided between “Train” and “Bus P&R” (park and ride); the multi-modal train charge points are located at train stations, and the Bus P&R charge points are situated at bus park-and-ride locations. Finally, the “Petrol Station” use case indicates a charge point is located on the grounds of an existing petrol station. Table 1 displays the number of charge points per use case within the dataset.

Whilst the monitored charge points are located throughout Ireland, it is anticipated that the results of the study will be applicable to charging infrastructure planning in other countries. The universality of the research can be viewed in both a geographical context and with respect to comparisons between the characteristics of transport sectors in other countries. Regarding the geographical context, Ireland is an island nation with moderate distances between major cities and reasonably large commuter belts adjacent to the cities. The cities are well-connected via motorway networks and a majority of the population (approximately 40%) lives within the capital city, Dublin, and its surrounding areas. As such, the results are relevant to other countries with a majority population based in the capital city and with additional cities located within moderate distances to the capital. In addition, concerning the charge point use cases, as the data are based on the charging infrastructure within an entire country this takes into account regional differences in charge point usage, which thereby provides more conclusive results. With regard to the comparisons between the characteristics of Ireland's transport sector and those of additional countries, Table 2 provides information on the transport sectors in six countries: Ireland (IE); the United Kingdom