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An evidence-based approach for investment in rapid-charging infrastructure

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ABSTRACT

To date, real cost data for Electric Vehicle (EV) rapid charging infrastructure is largely missing in the literature, preventing development of economic models to encourage private investment and limiting policy decisions. A business model has been constructed using actual capital expenditure, operating costs and usage data from the Rapid Charge Network project (RCN) which can be used to assist future investment and policy decisions. The model is run under a wide spectrum of EV uptake scenarios to provide plausible answers to a variety of research, policy and investment questions, including minimum growth rates to break even under current policy. Using real-world data we have confirmed that a financial business opportunity does exist for investment in rapid chargers on main highways and have identified the operating area in which a profit can be made. However, since UK EV adoption is still at the Innovators stage in a niche market where innovations in technology, user practices, supporting infrastructure and functionality are still required to achieve wide user acceptance, the case is also made for continued fiscal incentives to encourage investment in rapid-charging infrastructure.

1. Introduction

Transport is a major source of greenhouse gas emissions which cause global climate change. The transport sector is the second largest contributor to greenhouse gas emissions in the European Union (EU), after the energy sector, but it continues to grow as a key enabler of economic prosperity and quality of life indicator. Therefore many European countries have introduced policy measures aimed at reducing transport emissions. The EU's Clean Power for Transport policy (European Commission, 2013) seeks to break Europe's dependence on oil for transport, and therefore sets out a package of measures to facilitate the development of a single market for alternative fuels for transport in Europe. The Deployment of the Alternative Fuels Infrastructure Directive 2014/94/EU (European Commission, 2014) requires Member States to adopt national policy frameworks for the market development of alternative fuels and their infrastructure.

In many countries EVs have been the major manifestation of alternative fuelled vehicles, with the UK being active in EV demonstration, roll-out and the introduction of supporting recharging infrastructure since 2010 (Herron and Wardle, 2015). UK ULEV sales continue to grow significantly, showing an 89% increase between 2014 and 2015, and the percentage of new car registrations rose from 0.2% in 2013 to 1% by 2015 (Department for Transport, 14 April, 2016). However, this is lower than in other countries which have been more successful in encouraging ULEV uptake, such as Norway at 18% and the Netherlands at almost 8% (ACEA, 2015). A significant increase in growth is still required to meet the UK Committee on Climate Change's (CCC) target in which ULEV market share reaches 60% by 2030 to enable the UK to meet its legally binding target for greenhouse gas reduction.

The UK Government believes that public chargers, also known as EVSE (Electric Vehicle supply equipment), are necessary to encourage and enable the uptake of EV and its Office for Low Emission Vehicles (OLEV) has therefore been incentivising public bodies to provide EVSE since 2011 (Office for Low Emission Vehicles, 2013). However, it is also keen to see private initiatives entering the marketplace and so has

Abbreviations: CAPEX, Capital expenditure; CCC, Committee on climate change; DNO, Distribution Network Operator; DSO, Distribution System Operator; EMSP, Electromobility service provider; EU, European Union; EV, Electric Vehicle; EVSE, Electric Vehicle Supply Equipment; ICE, Internal combustion engine; IRR, Internal rate of return; NCF, Net cash flow; NPV, Net present value; OLEV, Office for low emission vehicles; OPEX, Operating expenditure; RCN, Rapid Charge Network project; RFID, Radio Frequency Identification; TEN-T, Trans-European Network – Transport; ULEV, Ultra-low emission vehicle; ZCF, Zero Carbon Futures Ltd

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reduced its incentives for vehicles and recharging infrastructure from early 2016. Therefore, it is critical that credible business models are developed which will attract private investors into this marketplace. Ecotricity's Electric Highway network, a UK renewable energy supplier operating a national highway-based rapid charging network, is one such private initiative.

This is a classic "Chicken and Egg" conundrum. Consumers continue to state that a lack of public recharging facilities is a barrier to drivers deciding to purchase EV (Office for National Statistics, 2016). Drivers want the comfort of knowing they can recharge if and when required, even if they subsequently don't often use the public EVSE provided to meet those perceived needs (Franke and Krems, 2013; Hübner et al., 2013). Recharging infrastructure varies in cost depending upon desired capability (power, speed, outlets) and location. This paper focuses specifically on rapid EVSE located along main highways, which can charge EV to 80% state of charge in under 30 minutes using Mode 3 and Mode 4 connections, but currently cost the most to build. Moreover recharging infrastructure falls outside of the EV manufacturers' traditional area of activity, creating an ongoing debate about who is responsible for public EVSE provision and ownership. In order to enter the recharging infrastructure market potential private investors require some certainty about return, which has been difficult to provide to date in this nascent market. This paper directly addresses this by developing a full business case for investment in rapid EVSE using real-world costs, in order to assess the conditions required for success in different scenarios. The results are derived from an economic evaluation performed using data from the RCN project and the findings can be used to inform potential investors and policy makers alike.

The objective of this paper is to use real-world cost and recharging data to investigate whether a feasible financial business case exists for EVSE rapid charging on main highways, and to identify the conditions required for its success.

The article is divided into 9 sections. This introduction is followed by a synopsis of the RCN project which provided the data for this research, followed by the UK's policy position. The challenges facing the business model for public rapid charging infrastructure provision are then summarised, referring previous literature to RCN's findings. The roles of the various stakeholders in this business model are then described alongside the methodology used for the study. The inputs to the model and its assumptions are set-out and the findings are then described in more detail. Finally a series of conclusions are drawn to inform policy makers and potential investors. For ease of reference, the acronyms used in this paper are summarised in the footnote below .[1]

2. The Rapid Charge Network (RCN) project

The data used to inform these results was generated by the Rapid Charge Network project (RCN). The project's ambition was to enable EV drivers to drive further, by installing EVSE in the form of 74 multi-standard rapid chargers during 2014 and 2015. The route covered 1100 km of Trans European Network-Transport (TEN-T) defined priority highways across the UK and into Ireland, as shown in Fig. 1. The route spans Great Britain from East to West, and South to North, crossing over the Irish Sea at Stranraer to Belfast and at Holyhead to Dublin in Ireland.

74 EVSE (rapid chargers) were installed for public use along main highways, at 65 privately owned sites including motorway services, fuel stations and large retail sites. 59 sites were located in Great Britain (England, Wales and Scotland), 3 in Northern Ireland and 3 in Republic of Ireland. EVSE was installed to enable access from both sides of the highway, enabling use for both long distance journeys and local travel.

The EVSE was equipped with three tethered charging outlets, to provide IEC61851-1 Mode 4 DC charging at 44 kW power output through CHAdeMO and Combo 2 plugs, and Mode 3 AC charging at 43 kW through Type 2 plug as defined in IEC62191 standards. This multi-standard rapid charging approach breaks down a barrier to EV adoption by giving consumers confidence that they can recharge quickly where necessary, regardless of EV make or model (Blech and Kozdra, 2016). This EVSE approach benefits both EV drivers irrespective of EV model, and EVSE providers by maximizing their customer base whilst minimizing investment and space requirements. A maximum of two EVSE were located at any one site, and some sites subsequently experienced queues of EV waiting to recharge at busy times of day. Adding additional EVSE to cope with demand was outside the scope of the RCN project, but is now being addressed by the aggregator Ecotricity in the UK.

The chargers were operated under two existing free to use networks, Ecotricity's Electric Highway network in Great Britain and ESB's ecars network in Ireland, therefore there were no billing mechanisms in use during this study. Drivers were required to register with Ecotricity or ESB ecars, receiving an RFID card which provided access to all RCN chargers as part of the existing networks. A whitelist approval mechanism was used to enable Ecotricity and ESB ecars customers to roam between the two networks. Since the end of the RCN project, Ecotricity has introduced an app-based access system (without the need for upfront registration) and applied fees for the use of all its EVSE, including those installed by RCN, however this is outside of the scope of this paper.

The RCN study collected data from both EVSE and EV along the route, conducted questionnaires with over 200 EV drivers and installed data loggers in 40 EVs to monitor EV driving and charging behaviour, particularly distance travelled, energy efficiency, charging locations, frequency and energy drawn. Several of the EV manufacturers funding the project also supplied data, with the EV owners' consent, from their in-vehicle data loggers, providing a longitudinal data set that illustrated how driving and charging behaviour changed before and after rapid EVSE roll-out. In depth analysis of real-world driving and charging behaviour was therefore conducted, studying the changes as more chargers became available, alongside evaluating EV drivers' recharging requirements and willingness to pay for rapid charging services. One objective of the project was to assess the potential for investment in rapid charging networks, which utilized the EVSE data supplemented by EV driver questionnaire responses, and forms the basis of this paper.

The RCN project was funded by a consortium of four major EV manufacturers Nissan, BMW, Renault and VW plus Ireland's ESB ecars business, and was match funded by the EU's TEN-T programme (EC). Completing the project consortium were Zero Carbon Futures (ZCF) which delivered the project, and Newcastle University which performed the in-depth study work leading to the results presented here.

3. UK policy

Governments intervene where there is perceived to be market failure or in the early stages of market development to ensure that policy goals can be met. There is a risk that uncertainty will delay investment in new technologies such as ULEV, where public benefit is thought to outweigh private value to the company (Sierzchula et al., 2014). In addition, ULEV price and performance may be seen to compare negatively with the existing technology. However, it is vital that new technologies achieve sufficient early adopters to establish a market niche (Geels, 2002) so governments provide incentives to ensure there is sufficient demand.

The UK government has provided consumer incentives towards the purchase of ULEV cars (Office for Low Emission Vehicles, 2011) since 2011. The adoption of ULEV is essential to the UK government's goal of reducing greenhouse gas emissions to 50% of 1990 levels by 2025 (Committee on Climate Change, 2008) and reaching 80% reduction by

[1] Acronyms and definitions used in this paper.