Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up

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A B S T R A C T

The Multi-Level Perspective (MLP) framework on transitions is used to interpret European electric vehicle take up and auto mobility transition. It finds that environmental and energy security pressures have created a favourable landscape 'push' for Battery Electric Vehicles (BEVs) that in turn has encouraged and facilitated serious commitment from some manufacturers. Yet BEVs, as a niche product seeking to disrupt an entrenched and established regime, face significant multi-level forces acting as barriers against such a transition, which the paper explores. This combination of factors creates a situation where BEV market penetration remains far below the level required for mass market transition. For BEVs to 'cross the chasm' and gain an established foothold in the market and hence significantly disrupt the regime, more holistic and effective solutions are required. It is argued that, so far, this has yet to be fully taken on board by policy makers.

1. Introduction

Many governments seeking to reduce carbon emissions and oil dependency, and given urban air quality concerns, have invested significantly to support the transition to a greener, more sustainable automobility. In so doing, they have implemented a range of policy instruments to stimulate the design, manufacture and take-up of hybrids, fuel cell and especially Battery Electric Vehicles (BEVs). Manufacturers have responded by exploiting new technologies to produce alternatively fuelled vehicles (AFVs) that facilitate travel in smarter and more sustainable ways. However, to date the take-up of AFVs has been slower than anticipated, attaining only modest market share, nowhere near the level required to push such vehicles into the mainstream. This issue has stimulated considerable debate in academia and beyond in recent years, suggesting a range of issues that are influencing the take-up of AFVs as well as offering potential solutions that might help pave the way for a transition to mass market take-up in the short-medium term. However, a key research problem persists in that to date an in-depth conceptualisation of the complex multi-level forces that impact upon transition is lacking. Such analysis is critical to better inform solutions that can more effectively smooth the path to widespread adoption.

The aims of this paper are to address this gap using the Multi-Level Perspective (MLP) framework (Geels and Kemp, 2012) as a lens through which to interpret European BEV take up and automobility transition. The paper provides a meta-analysis of trends in Europe (through a detailed literature review, review of policy papers, demonstrator project results along with our own research) in order to present an holistic understanding of the complex socio, economic and technical forces operating at landscape and regime

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level that both push toward and pull against transition; whilst also informing more effective solutions that can drive transition beyond niche spaces toward real disruption of the established ICE regime. In concluding we offer reflections on the usefulness of the MLP framework as a lens through which to interpret pathways to transition and inform effective policy solutions. In identifying levers, barriers and solutions in particular at the national scale, we also note that in terms of BEV transition, protected niche space is often provided at the city and local/regional scale; this suggests that the MLP framework needs to better engage with place and space.

The paper focuses specifically on BEVs. BEVs have an all-electric drivetrain and are powered by a rechargeable electric battery. BEVs are argued to have many societal benefits including lower operating costs, lower pollution in terms of both global warming (CO_2 emissions) and in terms of urban air quality (such as NO_x emissions) and less frequently mentioned aspects such as "extending the human range of mobility" for groups in society less able to access mainstream private transport (Ulrich, 2005). These benefits, coupled with pressure from environmental and energy security drivers, have encouraged governments at the local, national and supra-national level to implement policy instruments that are designed to encourage consumers to switch to BEVs. Estimates suggest that some \$13–16 billion has been spent globally on such instruments between 2008 and 2014, almost half of which has supported R & D (GEO, 2015; Hao et al., 2014; Wesseling, 2016).

The paper is structured as follows. Section 2 outlines the methodology. Section 3 draws on data to present a 'state of the market' analysis for Europe which is mostly lacking from the present academic literature. Section 4 outlines the Multi-Level Perspective (MLP) framework used to analyse the transition towards BEVs and identify a range of levers pushing BEV adoption and barriers to BEV adoption. Section 5 examines in more detail the levers or 'drivers' that have created the landscape for BEVs to emerge as an alternative product in the automotive ecosystem. Section 6 uses the MLP framework to analyse existing literature, both academic and non-academic, and presents a typology of barriers to take-up. Section 7 briefly outlines a typology of potential solutions highlighted in the academic literature, which are identified as a target for future research. Section 8 summarises and concludes.

2. Methodology

To address the research problem, a comprehensive literature review was undertaken. Whilst others such as Rezvani et al. (2015) have previously conducted an in-depth review of the literature relating to electric vehicle adoption, their study focused solely on papers (16 in total) drawing on empirical consumer data and results. The intention here is to provide a more holistic review of the literature to fully capture the debate on barriers and drivers to EV adoption. The process followed in constructing the review began with searching a set of academic databases comprising Elsevier Science Direct, Springer, Sage, Taylor & Francis online, and Wiley; in addition to search engines such as Google Scholar. In interrogating these databases, a range of keywords were used. These included: automobility, electric vehicles, pure electric vehicles, battery electric vehicles, barriers, financial barriers, technical barriers, consumer barriers, adoption, solutions, consumer attitudes, transition to electric vehicles, and policy.

For the purpose of this study, the most influential articles were those discussing the transition to electric vehicle technology as well as those which identify the levers and barriers to adoption faced by consumers, consumer attitudes and behaviour, and policy, for example in the form of investment in the EV ecosystem and consumer incentive schemes. The analysis also recognised those studies which drew on the results of small scale demonstrator trials or larger surveys of consumers as being important. Outputs which discussed more technical elements of BEV design, such as well-to-wheel emissions or energy consumption, were deemed not relevant to this investigation. Additionally, the analysis also discounted those studies of other automotive technologies such as hydrogen power as being beyond the scope of this paper. As a result, over one hundred outputs in the form of journal articles and book chapters were utilised in the review of literature which underpins our holistic assessment of the levers and barriers to EV adoption presented through the lens of the Multi-level perspective framework.

In addition to academic literature, the paper draws upon EV sales and registration data to inform a 'State of the Market' Analysis. These were initially drawn and analysed from several sources: the Automotive Industry Data Newsletter, which since 2012 has published monthly statistics on EV sales and market share in western European countries; the National Automobile Manufacturers Association (ACEA) which publishes quarterly statistics for the full range of alternatively fuelled vehicles registered in European countries; and IHS Automotive which has produced statistics on EV sales and market share for leading countries globally. The purpose of using multiple sources was to provide robustness and reliability in the findings presented. Analysis revealed that there was good consistency in data across sources. Given their more regular publication, data from the Automotive Industry Data Newsletter were ultimately used and are presented below.

Alongside the sales data, reports from the Amsterdam Roundtable Foundation and McKinsey on *Evolution: Electric vehicles in Europe: gearing up for a new phase?*, the 'Global EV Outlook' and various media reports provided additional contextual data for the section on Levers pushing EV adoption.

3. State of the market: the European BEV market to date

Despite the scale of public support and investment, and while there are encouraging signs, the European BEV market is failing to 'spark' into life in a way that would suggest potential for mass market transition (Table 1). Whilst sales of BEVs are increasing, witnessing growth of 271% between 2012 and 2015 and over 50% growth between 2014 and 2015; 90,000 BEVs were sold in 2015, this represents an overall market share of just 0.7%.

Looking beyond the overall western European picture reveals considerable variation by country. Four countries – Norway, France, Germany and the UK – account for 75% of BEV sales in 2015, with Norway alone accounting for almost 30%. More strikingly, Norway achieved a market share for new sales of BEVs of over 17% in 2015, with Demark and Switzerland being the only other countries to