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Anxiety vs reality – Sufficiency of battery electric vehicle range in Switzerland and Finland

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ABSTRACT

Limitations of battery capacity in battery electric vehicles (BEVs) contribute to what is known as range anxiety, and therefore poses an obstacle to their mass-market adoption. While high-range BEVs have been recently introduced, it is not clear whether they will be able to cover all possible trips without long recharging detours, and what the infrastructure needs of those vehicles are. To understand the impact of range limitations in Switzerland and Finland, we constructed a simulation model that is based on representative national travel surveys. We use it to calculate the potential of BEVs to cover any trips and investigate options to increase this coverage. The options discussed in this paper are ways to facilitate easy recharging, such as infrastructure development policies. We complement our results with insights from three focus groups. The results suggest that 85–90% of all national trips could have already been covered with BEVs prevalent in 2016. If the charging station infrastructure is developed appropriately and high-range BEVs are adopted, it is possible to reach a potential coverage of 99% or more in both countries. Deploying charging stations at users' homes and in residential areas does contribute significantly to this improvement and is desirable from a car user's perspective. Providing fast-charging stations in other locations is necessary to maximise the potential. We recommend to focus policy efforts on the development of residential charging options and to increase the visibility of electro-mobility using fast-charging stations.

1. Introduction

The fossil fuel-dominated transport sector contributes to some of today's major problems. Road transport is responsible for approximately 17% of total greenhouse gas (GHG) emissions (Intergovernmental Panel on Climate Change, 2013) and exhaust gases are major drivers of local air pollution. Despite government initiatives to reduce such emissions and more and more stringent emission thresholds, internal combustion engine vehicles (ICEVs) are reaching natural limits in terms of their potential to limit both carbon dioxide and pollutant emissions. A prominent option to tackle these challenges is to increase the adoption of battery electric vehicles (BEVs) in passenger transport. Provided that the electricity mix originates from low-carbon sources, their total GHG emissions can be considerably lower compared to ICEVs (van Vliet et al., 2011; Zah and de Haan, 2012).

However, there are barriers to the mass adoption of BEVs, and we will focus on one of these: range anxiety in potential electric car

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Acronyms

AFI	Alternative Fuels Infrastructure Directive
BEV	battery electric vehicle
EPA	Environmental Protection Agency
EV	electric vehicle
FEDRO	Federal Roads Office
FNTS	Henkilöliikennetutkimus
GHG	greenhouse gas
GIS	geographic information system
HEV	hybrid electric vehicle
ICEV	internal combustion engine vehicle
MC	Monte Carlo
MZMV	Mikrozensus Mobilität und Verkehr
NEDC	New European Driving Cycle
PP	policy package
PHEV	plugin hybrid electric vehicle
SD	standard deviation
TUT	Tampere University of Technology

buyers. One important (but not sole) cause for range anxiety is the smaller range of BEVs compared to conventional cars. A smaller range can force a driver to change his driving patterns. If buyers are unwilling to adapt, they will prefer conventional cars. Since 2017, media coverage about more affordable BEVs with comparably high battery capacities and ranges of more than 300 km gained momentum, suggesting that this barrier could soon be a problem of the past. For example, Tesla, Opel, Nissan and other manufacturers all released new models with greater range, and other manufacturers announced they would introduce new BEVs in the future. Notably, Volvo stated their intention to only sell BEVs and hybrid electric vehicles (HEVs) from 2019 onwards. Moreover, the United Kingdom, France and China all announced to ban or phase out ICEVs in the near future (Ryan and Shankleman, 2017; The Economist, 2017). Despite progress on the vehicle side, it is not clear if current and future BEVs can cover all possible trips, and thereby mitigate range anxiety, given the current charging station network.

We examine and compare this coverage for Finland and Switzerland. We chose these two countries because they are opposites in many ways: Switzerland is small, densely populated except for the mountain areas, and people do not often travel long distances, whereas Finland is much larger and sparsely populated, with a tradition of spending weekends and holidays in countryside cottages.

Governmental policies could provide the means to overcome infrastructural barriers and facilitate the diffusion of BEVs into mass markets. Even though several hundred public charging stations already exist in both countries, and their number is increasing, a universal charging station network analogous to the network of filling stations seems to be a long way from realisation. To this end, the Swiss Federal Roads Office (FEDRO) recommends cantons and service area maintainers to install a network of fast-chargers at all main motorway service areas (Federal Roads Office, 2016). In the case of Finland and the EU, *Directive 2014/94/EU on the deployment of alternative fuels recharging and refuelling infrastructure* (known as Alternateive Fuels Infrastructure Directive (AFI)) directly addresses infrastructure development, i.e. it requires the EU member states to provide an appropriate number of publicly accessible charging points. The implementation draft of Finland proposes a market-based mechanism to build up this infrastructure (Ministry of Transport and Communications, 2016). But despite current policy efforts, a previous meta study states that further research is needed to better understand the infrastructure needs of future BEV models with higher ranges (Hardman et al., 2018).

This paper examines the aforementioned issues and explores whether the currently available and future BEV models and the charging stations network enables car users to cover all of their desired trips. Existing literature includes comprehensive studies about range needs and the effect of infrastructure deployment on BEV trips (see below), but nobody has, to our knowledge, extensively investigated the influence of policies on the share of successful BEV trips on a nation-wide level. Additionally, we do not know of any studies investigating and comparing these issues for the cases of Finland and Switzerland, apart from one study about plugin hybrind electric vehicles (PHEVs) in Finland (Rautiainen, 2015). Moreover, findings from other countries or powertrains are not easily transferable. We address these research gaps with the following three research questions:

1. What are car users' range needs?
2. What share of car trips can be successfully covered with the currently available (2016/17) BEVs and the current charging infrastructure?
3. How much can improved BEV range and an improved charging infrastructure increase the share of successful BEV trips?

We explore the first question using a combination of focus groups and modelling. As a means to quantify the share of successful BEV trips in question 2 and 3, we introduce and model the *BEV-potential* and define it as a share of trips that can be covered solely by BEVs given the availability of charging possibilities: i.e. we assume that not all households have the possibility to charge BEVs at their homes. Focus groups investigate the desirability of those charging possibilities.

Reaching a high BEV-potential does not guarantee that range anxiety in car buyers and users vanishes. As the following literature shows, psychological factors also play a role. The latter is not our focus and we leave these analyses to other scientists. We do however argue, that a high BEV-potential, i.e. the ability of BEVs to cover most or all trips is an important factor to mitigate range anxiety.

1.1. Range needs

In order to support the adoption of BEVs in the consumer mass-market, it is essential that policy makers understand factors and barriers influencing a car user's behaviour. Studies have shown that the limited range of BEVs, long charging times and public infrastructure availability constitute significant obstacles which can cause what is known as range anxiety (Rezvani et al., 2015; She