Energy xxx (2016) 1–8

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Dissemination of electric vehicles in urban areas: Major factors for success

Amela Ajanovic*, Reinhard Haas

Energy Economics Group, Vienna University of Technology, Austria

ARTICLE INFO

Article history:
Received 2 November 2015
Received in revised form
2 May 2016
Accepted 10 May 2016
Available online xxx

Keywords:
Electric vehicles
Policy
Emissions
Sustainable mobility

ABSTRACT

Problems of transport become more pressing with increasing urbanisation. Although EVs (electric vehicles) are considered to contribute to reduction of greenhouse gas emissions and local air pollution caused by passenger car transport, their use is still very modest.

The core objective of this paper is to identify the major impact factors for the broader dissemination of EVs in urban areas. We compare and analyse cities selected in nine different countries which are active in dissemination of EVs.

The most important recommendation for policy makers is that all monetary and non-monetary promotion measures implemented should depend on the environmental benignity of the electricity generation mix. From society's point of view the promotion of EVs make sense only if it is ensured that a major share of electricity they use is generated from renewables. Since the final goal is not just to increase the number of EVs but to reduce emissions, cities also have to consider other e-mobility options such as trolleybuses, metros, trams and electro buses, as well as promote walking and biking, especially for short distances.

1. Introduction

The transport sector is one of the major contributors to global energy consumption and GHG (greenhouse gas) emissions [15]. At the time when problems, such as increasing GHG emissions and air pollutions, as well as growing dependency on energy import, related to the conventional passenger cars transport based on fossil fuels, are becoming more and more visible, the use of alternative, environmentally friendly fuels and powertrains seems to be a key strategy for heading towards a sustainable transport system.

Especially in cities, where due to the urbanization trend transport developments are becoming even more important, there is an urgent need for action to cope with transport problems. Some of the problems related to urban areas such as local air pollution and noise, could be reduced by using zero-emission battery electric vehicles.

Since EVs (electric vehicles) have potential to contribute to the better life quality in cities as well as to the reduction of GHG emissions in the transport sector a broad portfolio of different policy measures is already implemented on national as well as local level all over the world with the goal to support their market-penetration.

The need for a more environmentally friendly energy and transport system is already included in the European energy and transport policy design [16]. According to the EU's Energy and Climate Change Packages (2020 and 2030) there is a clear target to reduce GHG emissions, increase energy efficiency and use of RES (renewable energy sources). A 10% share of renewable energy should be achieved in the transport sector by 2020 [51]. Furthermore, according to the Transport White Paper [14] the use of 'conventionally fuelled' cars in urban transport should be reduced by 50% by 2030, and in cities completely phased out by 2050. Looking at the current situation in urban transport, especially the very low share of alternative automotive powertrains and alternative fuels, these targets can be seen as very ambitious. Although different policy measures are implemented worldwide with the goal to reduce GHG emissions, supporting the use of alternative and more environmentally friendly vehicles directly or indirectly, EVs are still rarity in most cities.

Even if EVs were invented more than 150 years ago, and in spite of several attempts to make them more attractive, the passenger vehicle market is dominated by ICE (internal combustion engine)

* Corresponding author. Vienna University of Technology, Gusshausstr. 25, 1040, Vienna, Austria.
E-mail address: ajanovic@eeg.tuwien.ac.at (A. Ajanovic).

http://dx.doi.org/10.1016/j.energy.2016.05.040
0360-5442/

vehicles [2,7]. Over this period, many countries have launched extensive research and development programmes for battery and vehicles, and different technologies and business models have been tested [20,31,46].

Previous studies have analysed various aspects of the deployment of EVs especially their economic and environmental assessment (e.g. Refs. [2,18,56,58,59]). Their role in an urban context is analysed by Perujo et al. [43] and Trip and Konings [60]. Newman et al. [40] provided a critical discussion on urbanism and EVs. Similar analysis but with the focus on planning-related issues is documented by van Wee et al. [62]. More detailed investigations of specific electro mobility issues in different cities are provided by Colmenar et al. [10] for the Spanish city of Leon, by Raslavicius et al. [48] for city of Kaunas in Lithuania, by Jian [29] for Being and Perujo et al. [45] for the Province of Milano (Italy). The potential impacts of EVs on air quality in Spanish cities Barcelona and Madrid is documented in Ref. [52]. Public policies and knowledge which can trigger development of electric mobility is also discussed in literature, see e.g. Refs. [1,9,32,34]. A very good assessment of leading EVs promotion activities in US cities is provided by Lutsey et al. [35]. They have analysed the uptake of EVs in relation with different promotion actions set on the state and city level. There are also a few other publications providing an overview of EVs in different countries (e.g. Ref. [8]) and cities (e.g. Refs. [17,23]). Comprehensive assessments of socio-economic and socio-technical issues of EVs have been conducted by Plötz et al. [46] and Steinhilber et al. [57].

The core objective of this paper is to identify major impact factors for the broader dissemination of EVs in urban areas. We compare and analyze cities active in the take-up of EVs based on the literature. In this paper we have selected fourteen cities in nine different countries which are very active in dissemination of EVs. For the cities selected we were able to collect all data required for our analysis. In Europe, we have analyzed the impacts on the dissemination of EVs in Amsterdam, Barcelona, Berlin, Brabantstad, Hamburg, NorthEast, Oslo, Rotterdam, Stockholm, and Vienna; in the United States – Los Angeles, New York City, and Portland; and in Asia – Shanghai (China). All these cities are interested in the reduction of emissions and pollutions caused by transport and they have already implemented different national and local measures which should support the penetration of EVs.

The major novelty and contribution of this paper is that it addresses economic, environmental, infrastructural and political issues regarding the prospects for dissemination of EVs in urban areas, using specific data sets from various cities in the major geographical areas of EV use.

We have applied a mix of quantitative and qualitative approaches. For our quantitative approach we have used data from literature (e.g. Refs. [2,21,35], especially data provided by International Energy Agency [23,24,27,28] as well as national statistics [54,55]. We have investigated different indicators aiming to identify best examples for the EVs use in urban areas. For the qualitative analysis we have conducted a comprehensive literature review.

2. Background: Technical, economic and environmental characterstics of electric vehicles

The interest in EVs, which are often presented as ZEV (zero-emission vehicles), has been rapidly increasing over the last decade. EVs can be divided in four major types – BEVs (Battery Electric Vehicles), HEVs (Hybrid Electric Vehicles), PHEVs (Plug-In Hybrid Electric Vehicles), REX (Range Extenders) – with different level of electrification and different possibilities to contribute to emission reduction, see Fig. 1. Only pure BEVs are zero-emission vehicles at the point of use, but not in the whole WTW (well-to-wheel) energy supply chain. The advantages and disadvantages of different types

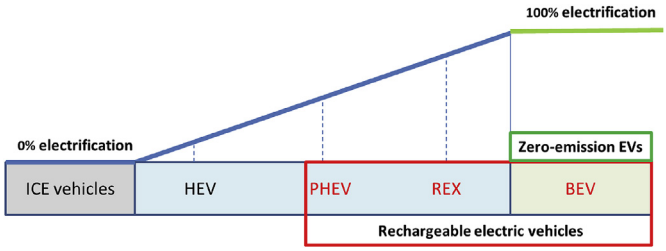

Fig. 1. Level of electrification of electric vehicles.

of EVs are discussed in detail in Ref. [2].

Currently, HEVs have the largest market share [53] since their characteristics as well as mobility costs are very similar to those of conventional ICE vehicles [2]. However, HEVs are powered by fossil fuels and have very low level of electrification, and consequently very limited potential for emission reduction. They can be seen just as an energy efficiency measure and hence are not suitable for urban areas.

There are much higher expectations with respect to EVs with higher electrification level. However, since rechargeable EVs have higher costs, lower operating range, as well as the need for charging infrastructure, their number is currently rather low. Major problems for faster market penetration are low density of battery, high costs and limited infrastructure, as well as acceptance.

To make EVs more economically competitive on the market they are supported by different financial policy measures. However, looking at the TCO (total cost of ownership), which can be calculated using Eq. (1), EVs are still more expensive comparing to conventional cars, mostly due to investment costs [2,22].

$$TCO = \frac{(IC + \tau_{REG}) \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O\&M}}{skm} \quad (\text{EUR}/100\ \text{km}) \qquad (1)$$

Where IC are investment costs; τ_{REG} is registration tax; α is capital recovery factor; skm is specific number of km driven per car per year; P_f is energy price incl. taxes; $C_{O\&M}$ are operating and maintenance costs; and FI is energy consumption of vehicles.

As can be seen from Eq. (1), TCO depend on specific number of km driven per car per year. This indicates that EVs could be more or less economic depending on travel activity. Vehicles with the high number of kilometre driven, such as taxis, delivery and service vehicles, could be more appropriate for electrification from an economic point of view.

Although EVs have lower or even zero emission at the point of use compared to conventional ICE vehicles, their total environmental benefits are very dependent on primary energy sources used for electricity generation. Yet, all environmental benefits of EVs could be reached only if the electricity used in cars is generated from renewable energy sources [3,56,59]. In case that electricity is generated from fossil energy, especially using old coal power plants, total WTW emissions could be even higher than those of conventional cars [5,11,56], see Fig. 2.

3. Performance of electric vehicles in cities selected

As mentioned by Newman et al. [40], EV City Casebook [23] is a very relevant source of examples of socio-technical experimentation, but a deeper assessment of these results is needed. In this paper we have analyzed cities selected considering not only absolute numbers of EVs and charging stations. We have investigated different indicators such as number of EVs per capita, number of EVs per charging point, relation between EVs per capita and GDP (gross domestic product) per capita, relation between gasoline and

Please cite this article in press as: Ajanovic A, Haas R, Dissemination of electric vehicles in urban areas: Major factors for success, Energy (2016), http://dx.doi.org/10.1016/j.energy.2016.05.040