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Methodology for assessing electric vehicle charging infrastructure business models

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HIGHLIGHTS

- Ecosystem is a network of actors who collaborate to create a positive business case.
- Electro-mobility (electricity-powered road vehicles and ICT) is a complex ecosystem.
- Methodological analysis to ensure that all actors benefit from electro-mobility.
- Economic analysis of charging infrastructure deployment linked to its usage.
- Comparison of EV ownership cost vs. ICE for vehicle users.

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ABSTRACT

The analysis of economic implications of innovative business models in networked environments, as electro-mobility is, requires a global approach to ensure that all the involved actors obtain a benefit. Although electric vehicles (EVs) provide benefits for the society as a whole, there are a number of hurdles for their widespread adoption, mainly the high investment cost for the EV and for the infrastructure. Therefore, a sound business model must be built up for charging service operators, which allows them to recover their costs while, at the same time, offer EV users a charging price which makes electro-mobility comparable to internal combustion engine vehicles. For that purpose, three scenarios are defined, which present different EV charging alternatives, in terms of charging power and charging station ownership and accessibility. A case study is presented for each scenario and the required charging station usage to have a profitable business model is calculated. We demonstrate that private home charging is likely to be the preferred option for EV users who can charge at home, as it offers a lower total cost of ownership under certain conditions, even today. On the contrary, finding a profitable business case for fast charging requires more intensive infrastructure usage.

1. Introduction

A business ecosystem is an economic community supported by interacting organisations (including suppliers, producers, competitors and other stakeholders), which produces goods and services of value to customers, who are themselves members of the ecosystem. The capabilities and roles and organisations evolve over time, but all of them have a shared vision to align their investments and to find mutually supportive roles (Moore, 1996). The term refers to "*communities of economic actors whose individual business activities share in some large measure the fate of the whole community*" (Moore, 2006, p. 33). This means that all actors can benefit from the existence of the ecosystem, but also that they need to contribute to it. Electro-mobility (the use of electricity for powering the drive trains of road vehicles[1]) falls within this definition, because it is a complex system where

Abbreviations: A, ampere; AC, alternating current; B2B, business-to-business; B2C, business-to-customer; CO_2, carbon dioxide; CS, charging station; CSO, charging service operator; DC, direct current; DSO, distribution system operator; EMSP, electro-mobility service provider; EU, European Union; EV, electric vehicle; ICE, internal combustion engine; IEC, International Electrotechnical Commission; l, litre; km, kilometre; kW, kilowatts; kWh, kilowatt-hour; O&M, operation and maintenance; RFID, radio-frequency identification; TCO, total cost of ownership; VAT, value-added tax

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[1] Due to the very diverse technologies and actors/roles needed to allow the change of paradigm in transport, electro-mobility cannot be understood without massive information and communication technology (ICT), in order to monitor both the state of the battery and the charging process, to manage and transmit all the data monitored and to inform EV users about different value-added services (charging station location and reservation, eco-routing, etc.).

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multiple actors interrelate with each other and must collaborate to make electro-mobility feasible. The economic and regulatory implications of this kind of complex environments have been analysed for different fields of the energy sector, in particular regarding energy efficiency programmes (Abrardi and Cambini, 2015; Eto et al., 1998; Hannon et al., 2013).

Although the adoption of electric vehicles (EVs) provides clear benefits for the society as a whole in terms of efficiency and environmental impact (Bohnsack et al., 2014; Gomez et al., 2011), it requires profound changes in the technologies to be used and in the roles to be performed by the different actors in the value-chain, which result in a number of barriers for its adoption. From the EV user perspective, main barriers include long charging times, shorter driving range and, especially, higher initial investment, even if running costs are lower for EVs when compared to internal combustion engine (ICE) vehicles. Moreover, the limited availability of charging stations (CS) for electric vehicles, which results from the high investment costs for their developer and the uncertainty about their use, is an additional barrier for EV users who cannot charge their EVs at home (Kley et al., 2011; Markkula et al., 2013; Wiederer and Philip, 2010).

Therefore, a sound business model must be built up for the charging service operator (CSO), so that it develops the required CS infrastructure while, at the same time, EV user experience must be improved, in order to overcome the barriers discussed above (Gomez et al., 2011; Kley et al., 2011; Markkula et al., 2013; Schroeder and Traber, 2012).

In general, a business model is a representation of how an organisation creates value for its customers and how that value is then shared between the organisation and the customers (Osterwalder and Pigneur, 2010; Magretta, 2002).

When dealing with business models related to electro-mobility, the whole ecosystem must be considered due to the complex interactions between stakeholders, many of which were not part of the value chain of neither ICE vehicles nor electricity supply (Kley et al., 2011). There are studies that focused on the business model for the car manufacturer (Bohnsack et al., 2014; Kley et al., 2011) or for the infrastructure developer (Markkula et al., 2013; Schroeder and Traber, 2012). However, an integrated view over the different stakeholders is still needed, which can be used for policy makers and regulatory bodies to design the policy and regulatory framework to better promote electro-mobility (Gomez et al., 2011; Kley et al., 2011).

According to Eto et al. (1998, p. 2), "*the overriding regulatory objective is the maximisation of social value or societal net benefits*". This means that the regulator aims at maximising the benefits for a set of involved stakeholders, while reducing their overall costs. If the regulator has perfect information about stakeholders' costs and benefits, the task of regulation design becomes easy, but this is not common in existing markets (Eto et al., 1998; Stoft and Gilbert, 1994) and even less in brand new environments as electro-mobility is. Moreover, regulation should promote a right allocation of benefits and efforts between the different stakeholders, which makes this task even more difficult, especially if the protection of vulnerable customers is also included as an additional goal for the regulator (Abrardi and Cambini, 2015).

In this context, this paper presents the results of an integrated assessment of the economic feasibility for different EV charging infrastructure options to help regulatory authorities best design the infrastructure deployment strategy. It is not the aim of this paper to provide exact results, but rather to provide an estimation of the potential for different charging alternatives, based on robust data sources and assumptions.[2] The study presented here considers average values for different parameters, instead of taking into account the very diverse potential alternatives that may happen.[3] This approach makes the analysis more straightforward and permits analysing different charging alternatives. Although it reduces the accuracy of the study, the future of electro-mobility is difficult to predict and the assumptions considered are expected to be good enough to identify future trends in CSO business performance.

Section 2 presents the roles of the actors in the electro-mobility ecosystem and defines the scenarios to be considered. Section 3 describes the methodology proposed and assesses the main cost components for the main actors. Section 4 shows the different case studies and discusses their main results. Section 5 summarises the main conclusions of the analysis.

2. Roles and scenarios

The ecosystem can only be sustainable in the long-term when every stakeholder obtains a positive business case, or a valuable good or service in the case of EV users. Stakeholders may be new entrants that want to create a new business, regulated companies, actors playing in competitive environments or end customers (EV users).

Due to the different regulatory options already envisaged (what Eurelectric (2010), Eurelectric (2013) call "market models"), the analysis presented here focuses on roles rather than on stakeholders. The new roles can be performed by new entrants or by established actors, but the duties and responsibilities will be defined by the role. Different regulatory options will result in one or more roles being performed by the same stakeholder, but they should not affect their profitability in competitive markets (Schroeder and Traber, 2012).

The electro-mobility service provider (EMSP) is one of the key new roles needed in the EV-ecosystem. It offers electro-mobility services to the end customers, which may include charging, search & find, routing and other services. It is the legal entity that the end-customer has a contract (business-to-customer (B2C) relationship) with for all services related to the EV. This provision of services, including the EV charging services (either at home, at work or at any other location), is the feature that characterises the EMSP. The EMSP is owner of the data of the EV users in its portfolio.

The CSO has the role of operating the physical equipment to supply the charging process of the EV. Moreover, it is responsible for the management of the charging session, as well as for monitoring, maintaining and controlling a certain CS. The CSO offers charging services (access to charging infrastructure, including energy) to the EMSP based on a business-to-business (B2B) relationship, either directly or through an agreement with a third party (e.g. a marketplace operator). It is the owner of all the data related to the CS.

A third new role is the Marketplace Operator. The marketplace is a virtual B2B environment (no end customers are allowed) for services related to electro-mobility, accessible through the internet and hosted in a cloud environment. Any business partner can

[2] This paper is based on the economic assessment performed in the EU FP7 project Green eMotion (http://www.greenemotion-project.eu/ (last access in June 2015)), whose outcome is summarised in Madina et al. (2015). Leading equipment manufacturers, electric utilities and car manufacturers contributed to several workshops where the data and assumptions were agreed, based on the best data available during the project execution phase.

[3] For example, each charging session will demand a different amount of energy, because not all the EVs will reach the CS with the same battery state of charge and not all of them will need to top up the battery; each EV user will have a driving behaviour and each trip will follow a different route, leading to different EV efficiencies; and there are different EV models available, in terms of size, weight, battery capacity, efficiency, etc.