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# Electric vehicle parking in European and American context: Economic, energy and environmental analysis

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ABSTRACT

The transportation sector faces increasing challenges related to energy consumption and local and global emissions profiles. Thus, alternative vehicle technologies and energy pathways are being considered in order to overturn this trend and electric mobility is considered one adequate possibility towards a more sustainable transportation sector.

In this sense, this research work consisted on the development of a methodology to assess the economic feasibility of deploying EV charging stations (Park-EV) by quantifying the tradeoff between economic and energy/environmental impacts for EV parking spaces deployment. This methodology was applied to 4 different cities (Lisbon, Madrid, Minneapolis and Manhattan), by evaluating the influence of parking premium, infrastructure cost and occupancy rates on the investment Net Present Value (NPV). The main findings are that the maximization of the premium and the minimization of the equipment cost lead to higher NPV results. The NPV break-even for the cities considered is more "easily" reached for higher parking prices, namely in the case of Manhattan with the higher parking price profile. In terms of evaluating occupancy rates of the EV parking spaces, shifting from a low usage (LU) to a high usage (HU) scenario represented a reduction in the premium to obtain a NPV = 0 of approximately 14% for a 2500 € equipment cost, and, in the case of a zero equipment cost (e.g. financed by the city), a NPV = 0 was obtained with approximately a 2% reduction in the parking premium. Moreover, due to the use of electric mobility instead of the average conventional technologies, Well-to-Wheel (WTW) gains for Lisbon, Madrid, Minneapolis and Manhattan were estimated in 58%, 53%, 52% and 75% for energy consumption and 66%, 75%, 62% and 86% for $CO_2$ emissions, respectively.

This research confirms that the success of deploying an EV charging stations infrastructure will be highly dependent on the price the user will have to pay, on the cost of the infrastructure deployed and on the adhesion of the EV users to this kind of infrastructure. These variables are not independent and, consequently, the coordination of public policies and private interest must be promoted in order to reach an optimal solution that does not result in prohibitive costs for the users.



*Abbreviations*: EMEL, Empresa Pública Municipal de Mobilidade e Estacionamento de Lisboa; EU, European Union; EV, electric vehicle; EVUE, Electric Vehicles in Urban Europe; HU, high usage profile; ICEV, internal combustion engine vehicle; ICT, information and communications technology; LU, low usage profile; MOVELE, Madrid electric mobility project; NPV, net present value; RE, renewable energy; SGORME, Sociedade Gestora de Operações da Rede de Mobilidade; SOC, State of Charge; TTW, Tank-to-Wheel; USA, United States of America; VKT, vehicle kilometer travelled; WTT, Well-to-Tank; WTW, Well-to-Wheel.

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## 1. Introduction

The transportation sector faces increasing challenges namely in its rising energy consumption and emissions profiles. In Portugal, in the 1990–2010 period, the emissions from the transportation sector increased by 84%. Among other factors, this growth is due to increasing road transport volume and vehicle kilometers travelled, both associated with increasing mobility needs, the increase in household income and the strong development of road infrastructure (APA, 2012). At an European level, urban traffic is responsible for 40% of $CO_2$ road transport emissions and it is estimated that 9 out of 10 European citizens are exposed to harmful particle emissions that are above the limit values (EEA, 2012). Additionally, the transportation sector is highly dependent on fossil fuels, with inherent consequences regarding disruptions of energy supply and price volatility.

As a result, alternative vehicle technologies and energy pathways are being considered in order to overturn this trend. Electric mobility is seen as one of the possibilities in the direction of a more efficient and less polluting technology. EVs have no tailpipe emissions and can strengthen security of energy supply through a broad use of renewable and low carbon energy sources (Baptista et al., 2012, 2010; Pina et al., 2014). The Portuguese electricity mix included approximately 40% of renewable sources in 2012 (Naturlink, 2012). However, electric mobility presents some drawback, such as the need of a charging infrastructure, purchase cost, performance, autonomy and charging limitations (Valentine-Urbschat and Bernhart, 2009). In terms of the need for a charging infrastructure, it represents a large investment, requiring the development of usage business models (Urban Act, 2012), for a still very small market regarding electric vehicle's deployment. Moreover, in the case of a public infrastructure, it will compete with an already existing and strong market of conventional vehicle parking in urban context.

In the user's perspective, these alternative types of vehicles bring with them new challenges, such as vehicle recharging and management, so it is still not clear what the potential EV market will be (Mendes Lopes et al., 2014) and how users will adapt to this new vehicle technology, which has been recently addressed in several studies in terms of EV adaptation (Bunce et al., 2014; Rolim et al., 2013; Southwest Research Institute, 2011) and charging routines (Caperello et al., 2013; Franke and Krems, 2013).

Several electric vehicles are commercially available (e.g. Nissan Leaf, Mitsubishi iMiev, Renault Fluence, Renault Zoe). Moreover, in the Portuguese context, the Government promoted in the past the deployment of a public charging infrastructure, with 1300 standard public charging points and 50 fast public charging points. This strategy, together with the incorporation of high levels of renewable energy in its electricity generation mix, envisioned to strategically develop specific industries in Portugal such as wind power turbines, solar panel and battery production (MEI, 2009). However, due to their high purchase cost, their market penetration has been low. In Portugal, the sales of EV have peaked in 2011 with approximately 200 units being sold (ACAP, 2012). However, after that, the 5000 € government purchase benefits has been removed, lowering EV sales dramatically.

In 2011, of all vehicles (51.1 million) sold within the global markets of EU, USA and key Asian markets (Korea, Japan and China) only 0.06% (~40,000) were electric vehicles. Of these 41% were sold in the USA, 27% in Europe and the remaining in the Asian markets (Proff and Kilian, 2012).

Regarding electric mobility business models, these have been studied mainly within the framework of European projects. That is the case of the Electric Vehicles in Urban Europe (EVUE) project and the Green eMotion project. The EVUE project focused on the exchange and dissemination of solutions to the barriers that electric mobility faces, such as public resistance, lack of infrastructure, rapid technology change and obsolete economic modeling (Urban Act, 2012). The Green eMotion project provided a business analysis of the relevant business scenarios for the ICT marketplace and also performed an assessment of the critical success factors for the deployment of services to sustain EV (Weidlich et al., 2012).

Regarding scientific studies, Kley et al. (2011) defined an holistic approach to developing business models for electric mobility. This study addressed the vehicle together with the battery, the infrastructure system and the system services that integrate electric vehicles into the energy system. Concerning the infrastructure characteristics the authors focused mainly on the technological issues, such as the type of connection or the type of power supply. Likewise, Román et al. (2011) presented a conceptual regulatory framework for charging EVs. In this research, the agents involved in the electricity market, in the development of the charging infrastructure and in providing charging services, as well as the several charging modes were considered. All market agents and their commercial relationships were analyzed.

However, few studies have addressed the economic impacts of deploying this type of charging infrastructure in different contexts. According to this framework, this research focused on the development of a methodology to quantify the economic, energy and environmental impacts of EV parking charging stations deployment for 4 different case studies, two in Europe and two in the USA. Moreover, variables such as the parking premium (a surplus percentage of the parking price), equipment cost and occupancy rate are explored in more detail. Finally, the energy and environmental impacts of the mobility provided by the deployment of the charging points are estimated.

## 2. Methodology

### 2.1. Model development

In order to assess the economic feasibility of deploying EV charging stations and to quantify the energy and environmental impacts of EV charging stations at a city scale, a model was developed, which was named Electric vehicle parking business