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External costs of electric vehicles

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ABSTRACT

Electric vehicles (EV) are often considered a promising technology to decrease external costs of road transport. Therefore, main external cost components are estimated for EV and internal combustion engine vehicles (ICEV). These include costs of accidents, air pollution, climate change, noise, and congestion. All components are estimated over the product lifetime and, where appropriate, differentiated according to fuel type, vehicle size as well as emission location and time. The advantage of this differentiation is, however, compensated by high uncertainties of most cost estimates. Overall, the external costs of EV and ICEV do not differ significantly. Only for climate change, local air pollutants in congested inner-cities, and noise some advantageous effects can be observed for EV. The advantages depend strongly on the national electricity power plant portfolio and potentially also on the charging strategy. Controlled charging might allow for higher emission reductions than uncontrolled charging of EV.

Introduction

In 2012, almost the entire (99.8%) global vehicle stock was still based on internal combustion engine vehicles (ICEV) using petroleum-based fuels (Clean Energy Ministerial et al., 2013). Europe is highly dependent on these fuels imported mainly from the Middle East and Russia (IEA, 2012a) and road transport induces several environmental problems (e.g. acidification and eutrophication, ozone alarm, particulate matter, noise nuisance, etc.). Hence, road transport is a key sector in the context of environmental protection and energy security.

Currently, climate change is in the focus of politics, public, and scientific literature. In the European Union (EU-27), the emissions of the most relevant greenhouse gas (GHG), carbon dioxide (CO_2), were reduced by almost 12% between 1990 and 2010, whereas the transport sector increased its CO_2 emissions by 20.6% during the same period. In the new EU member states this increase even reached 58.5% versus a decrease in overall CO_2 emissions by 29.5% (Eurostat, 2013). These trends are expected to continue, although somewhat weakened (JRC, 2008). In view of these trends, high technical CO_2 abatement costs, and the expected change of conduct, many studies came to the conclusion that transport will be among the last sectors to bring its emissions down below current levels (e.g. Stern, 2006, Annex 7c and Skinner et al., 2010). On the global scale, the situation is even more severe. The World Business Council on Sustainable Development (WBCSD, 2004) expects the global vehicle fleet[1] to more than double until 2050. This is supported by several other studies (cf. Gomez-Vilchez et al., 2013).

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[1] This means light duty vehicle (LDV) fleet and includes most conventional passenger cars (with a payload capacity of less than 4000 lb, i.e. 1814 kg).

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Electric vehicles (EV) might help to master some of those challenges (e.g. Anable et al., 2012). Even though this idea is not new (cf. Hamilton, 1980), the electrification of the road transport sector is said to be an ecologically promising pathway. Some studies show that the marginal abatement costs for GHG emissions are lower compared to ICEV (Hacker et al., 2009, and TNO et al., 2006). Needless to say, EV have considerable external costs which highly depend on the electricity generation during the EV's lifetime and for the construction of the vehicle and battery (e.g. Bickert and Kuckshinrichs, 2011). Besides the impact on GHG emissions there are several other influences on the environment and the society, which are not jet explicitely considered in the users' utility - and are therefore extrenal costs. Economic concepts for measuring and internalising external costs seem convenient to identify these effects (cf. Proost and Van Dender, 2012). We therefore apply this concept in the following and compare the external costs from EV with those from ICEV.

Even though EV have been existing as long as ICEV, they were rather insignificant during the last century and gained relevance in recent years only. This recovery was mainly driven by the pressure of rising GHG emissions and high fuel dependency of industrialised countries as well as by strong breakthroughs in battery development (cf. Nykvist and Nilsson, 2015). To date, a number of studies have dealt with the environmental impacts of EV – most of them focusing on CO_2 emissions (e.g. a broad literature overview by Hacker et al., 2009). In addition, first in-depth studies (e.g. Torchio and Santarelli, 2010) were published, with some even using life cycle assessment (LCA) approaches (cf. Hawkins et al., 2012a,b; Messagie et al., 2010; Lane, 2006). For Germany, e.g. Helms et al. (2013), Zimmer et al. (2011), and Peters et al. (2012) provide first analyses. However, current literature remains at the level of average driving cycles, averaging urban and rural travel. In the discussion on charging vehicles according to their local and temporal impact, as promoted by the European Commission's vision of marginal social cost pricing (MSCP) for all transport modes, more disaggregated figures of the external costs of EV in comparison to ICEV are needed. The present paper aims at shedding some light on this issue taking into account the transport and energy sectors.

We are well aware that environmental and climate issues are important challenges for the transport sector Creutzig et al. (2015), but do not capture completely the social burden of transport. Current policies and visions on sustainable transport try to get cars completely out of the city centers (cf. Anas and Lindsey, 2011) – a place where EV have their main environmental advantage over traditionally powered cars. We also pay attention to safety and congestion issues. Space consumption and the separation of cities by busy roads will be discussed qualitatively. Furthermore, our analysis will focus on pure battery electric vehicles (BEV) even though other EV, such as plug-in hybrid electric vehicles (PHEV) or range-extended electric vehicles (REEV), will probably have a much higher market potential (Kay et al., 2013). Their emissions, however, are somewhere between the ICEV and the BEV.

The structure of this paper is as follows: We give a short introduction to external costs in the next section, before outlining current external costs of ICEV (i.e. external costs of accidents, air pollution, climate change, noise, congestion as well as other external costs) in chapter three. As the market share of EV seems to be rather low before 2030 and as vehicle technology as well as electricity consumption will improve until then, we give an outlook on external costs until 2030. Then, in chapter four, the current and future external costs of EV are given. A comparison of the external costs of ICEV and EV completes this paper.

External costs

Overview

Challenges associated with measuring external costs of transport are serious (cf. Verhoef, 1994). However, in order to compare the environmental sustainability of different modes and technologies, the concept of external costs is hardly evitable. Their (uniform) assessment is claimed to be necessary for reasons of equity and international comparisons (e.g. CE Delft et al., 2008). The challenges in assessing external costs are mainly based on the different impacts due to individual local conditions (e.g. different vulnerability or population density) or complex interdependencies of the emission and its impact (e.g. the statistically proven impact of noise emissions on life time or the evaluation of long-term impacts of climate change) (cf. Jochem and Rothengatter, 2011).

In the past, approaches to measuring external costs temporarily prevailed. However, methods for willingness to pay and willingness to accept concepts, such as stated or revealed preference approaches, were criticised strongly throughout the 1990s (e.g. by Rosenthal and Nelson, 1995; Hausman, 1993; Diamond and Hausman, 1994). Even the more recent contingent valuation approach is increasingly criticised (e.g. Hausman, 2012). The development of new methods (e.g. with the help of data envelopment analysis) is continuing (Kuosmanen and Kortelainen, 2007). However, emergence of an all-convincing approach remains highly unlikely.

Besides these challenges in the evaluation methodology, the considered time horizon (cf. Fouquet, 2011), system boundaries, technical measurement, cost category (e.g. marginal vs. average), equity, handling of subjective evaluations, etc. are highly contentious issues when assessing external costs. They may be obstacles when comparing different results. Notwithstanding the concept of external costs serves as a basis for many environmental policies. Therefore, comprehensive best practice approaches for different cost categories (e.g. from CE Delft et al., 2008:8) have been used so far to cope with this contradiction and to give sound estimates for their internalization (e.g. in Maibach et al., 2008; UBA, 2012; Korzhenevych et al., 2014). Despite these uncertainties, we compare the external costs of ICEV with those of EV and try to indicate the corresponding uncertainties in the following sections. We consider (where possible) the product lifetime of the vehicle by