Smartphones for Energy Efficient Driving of Electric Cars: Analysis of Economical and Ecological Effects and Saving Potentials

Bachelorarbeit

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1. Introduction

Electric cars (EC) will replace the conventional driven cars (CC), represented by gasoline and diesel, in a long term view. Due to the finiteness of fossil fuels it is necessary to conduct a continuous research and development of alternative modes of driving. With technical progress in the fields of battery technology and automotive industry ECs already became more competitive compared to CCs in the past few years. However, as the admission statistics show, ECs still suffer acceptance problems (cf. KBA, 2015a) conditioned by their main disadvantages: the high acquisition costs, the range anxiety and the long charging time of the battery (Götz et al., 2011, p. 7).

The acceptance of ECs among the potential users is mainly influenced by economic and ecological aspects (Götz et al., 2011, p. 6). Economic aspects are represented by the acquisition, energy and maintenance costs of the vehicle. Ecological aspects contain primarily the greenhouse gas (GHG) emissions in the form of carbon dioxide (CO_2). With an advancing climate change and global warming, the topic of environmental sustainability becomes more important to the society. ECs cannot be seen as zero-emission-vehicles because of their manufacturing process and the production of the electricity they consume. The energy mix is a fundamental driver of the GHG emissions of an EC. The higher the share of renewable energy sources (e.g. solar-, water- and wind-energy) in the energy mix, the lower the GHG emissions. Energy made of fossil fuels like coal causes a higher pollution (cf. Icha, 2014, p. 8). The environment-friendliness of an EC is therefore immediately connected to the underlying energy mix of the respective producer.

One instrument to overcome the acceptance problems of ECs might be smartphones which are widespread in Germany. In 2015, there are 45.6 million smartphone users in Germany representing about 55% of the national population (cf. Statista, 2015a). Smartphone applications may increase the acceptance of ECs by promoting a defensive driving style which will lead to a decrease in energy consumption resulting in reduced operating costs and less GHG emissions. Smartphones can have influence on the motorists, as they can provide relevant and appropriate information. The connection between information systems (IS) and creating a sustainable society is referred to as “Green IS” (cf. Watson et al., 2010, p. 24). In order to reach a sustainable situation and mitigate global warming, the GHG emissions caused by motorised mobility should be as little as possible. Thus, all possible savings should be identified and realised, if they are practicable.

This thesis will explore single and aggregated saving potentials of ECs by using smartphone applications on a macroeconomic level (Germany). Even though some research has been done in connection with IS, sustainability and mobility, there is less investigation of aggregated effects and future scenarios. To fill this research gap, the following research question is being examined in this thesis:

What effects do smartphone applications have on the charging costs of an EC and to what extent do they enable a reduction of GHG emissions of the car fleet in Germany?

To investigate this question, this thesis is designed as follows: In chapter two the theoretical fundamentals are given by first presenting the status quo of current research by means of a literature review according to Webster and Watson (2002). Thereafter, the theory of reinforcement is introduced to explain why smartphones can be a medium to implement a defensive driving style and save energy. Furthermore a few exemplary mobile applications are illustrated to show the general functionality of the smartphone utilization in an EC.

In chapter three the saving potentials of smartphone applications are calculated on a single-car basis and an aggregated-basis, including the total German EC fleet. After presenting necessary basic assumptions and the current circumstances of the electric mobility in Germany, the economic saving potentials are calculated. Besides the computation of possible monetary savings enabled by mobile applications, the EC's recharging cost are compared to the CC's refuelling cost in order to investigate the competitiveness of ECs in everyday life. In addition, the ecological saving potentials are calculated by projecting the possible GHG savings due to the smartphone integration in an EC. Also in the context of environmental-friendliness, ECs are compared to CCs. After computing the saving potentials under present conditions, three possible future developments of the underlying influence factors are examined in order to point out different future situations in Germany. As the saving potentials are connected to these developments, the quantity of possible savings will vary between the scenarios.

Based on the results of the calculations in chapter three, the findings are discussed in chapter four by evaluating the outcomes and the computation approach. Moreover, implications for research and practice are given, which are derived from the findings and several assumptions.

Chapter five deals with the underlying limitations of the thesis, which are mainly represented by the assumptions that had to be made in order to perform the calculations of the saving potentials.

Finally, the conclusion takes place to summarize the findings and give an outlook for the future challenges of electric mobility in Germany.

users, it is difficult to estimate this proportion appropriately. Thus, three different developments are stated.

Due to the fact, that several influence factors change simultaneously in the scenario analysis, the single impact of each factor cannot be isolated. However, changing only one factor would not reflect reality.

All in all, one can state that there are relevant limitations of the thesis, which can influence the results of the calculations significantly. The actual developments of the factors are determined by different impacts, which should be recorded constantly to respond to undesirable outcomes as quickly as possible.

6. Conclusion and Outlook

In order to sum up, the utilized approach and obtained results are summarised below. The goal of this present thesis was to calculate the economic and ecological saving potentials of ECs by integrating smartphone applications in cars. Whereas this savings relate to the recharging cost and GHG emissions, they should relate to single (one EC) and aggregated effects (EC fleet) in Germany under current and future circumstances.

First, the theoretical basics are given to achieve a better understanding of the performed calculations. By conducting a literature review regarding the connection of ECs, smartphones and energy efficiency, there is presented an overview of the current state of research to the mentioned topic. The result of the review was that none of the considered 15 studies included all six fields of the concept matrix which demonstrates the research gap this thesis aims to fill. Thereafter, the Theory of Reinforcement is introduced to understand why a person should use a technical tool, like a smartphone, to change his/her behaviour in terms of driving more energy efficiently. The smartphone and the including mobile application can be seen as part of a learning process with the goal of becoming a more energy efficient motorist. After that, three smartphone applications are presented exemplary in order to show the general functionality of a driver assistance system that induces a person to drive more defensively. Besides the realisation on a smartphone, some applications are also available as on-board systems that are integrated in the car-IT directly which might increase the user acceptance.

Moreover, the calculation of the saving potentials take place in chapter three. In terms of competitiveness, the EC's recharging cost are compared to the CC's refuelling cost under current conditions, resulting in an absolute advantage of ECs regarding city- and urban-surroundings. In the mixed-profile, the diesel model of the VW Golf shows the lowest cost, whereas the gasoline model has the highest refuelling cost across all route profiles.

Based on an energy saving of 9.5%, integrating mobile applications like Smooth Driver in an EC can save 52.4 - 71.3 €/a under today's conditions, depending on the area of operation. Projecting this potential on a national level, the current German EC fleet of 18,948 ECs could reach maximum savings of 1,351,887 €/a in mixed-conditions, if all EC motorists would drive defensively.

Besides monetary aspects, the ecological side is considered as well. By performing a WTW-analysis, the CO_2-emissions are compared between ECs and CCs. The significant lower GHG emissions of the EC, even under today's conditions, lead to the recommendation of substituting CCs with ECs from a purely ecological perspective. Thereby, relative savings of 37.64 - 55.56% (10.82 - 32.65%) compared to gasoline cars (diesel cars) are reachable for ECs. By integrating smartphone applications, a single EC can save 7.5 - 10.2 gCO_2/km, resulting in annual savings of about 108 - 147 $kgCO_2$, depending on the route profile. If the mobile application user share across the German EC drivers would be 100%, the aggregated saving potential could amount around 2,051 - 2,791 tCO_2.

As the actual developments of the underlying influence factors are unpredictable for the future, a scenario analysis is conducted in order to simulate three different possible movements. The Green Scenario describes an intensive utilization of renewable energies, leading to a significant decrease of the Emissionsfaktor Inlandsverbrauch. This factor mainly determines the general environment-friendliness of ECs since it represents the GHG emissions of the power generation. In addition, the number of ECs and the mobile application user share in ECs increase in a large extent, leading to the highest possible aggregated saving potentials (149,597 tCO_2/a and 133,730,535 €/a in 2030). To reach this development, the government is called to initiate appropriate incentives and support measures e.g. providing direct subsidies to the purchase of an EC. The high proportion of renewable energy sources in Germany would increase the electricity price slightly for about 0.015 €/kWh from 2020 to 2030, resulting in higher annual cost of recharging (ca. + 56 €). It must be pointed out that this development is optimistic and will be difficult to realise. Thus, two other scenarios are created.

The Medium scenario contains a moderate development of the underlying influence factors, as it continues more or less with the changing rates of the last years. Compared to the Green Scenario, the aggregated ecological saving potential amounts about one third of the saved GHG emissions in 2030. The aggregated monetary saving potential accounts for ca. 28,838,840 € in 2030, representing about 21.6% in comparison to the “Green Scenario”.

The third scenario describes a stagnating development of the underlying influence factors, leading to a low number of registered ECs and a small saving application user share. The aggregated saving potentials still expand in the future but in a severely weakened extent, resulting in aggregated ecological savings of 3,644 tCO_2/a in 2030. The total monetary saving potential of the German EC fleet in 2030 amounts ca. 1,878,205 €/a. Overall, the scenario analysis shows the impact of different developments regarding the influence factors, resulting in outcomes that distinctly differ from each other. In order to enable saving potentials as large as possible, the number of registered ECs in Germany and the smartphone integration need to be raised in future.

The numbers show the large saving possibilities of a smartphone integration on a macroeconomic level. That fact leads to the implication that there should be more research and information campaigns in the field of mobile applications in order to achieve economic and ecological savings. Furthermore, smartphones are not the only technological medium, which can provide relevant information for the motorist, as existing on-board solutions of saving applications demonstrate.

All in all, the underlying influence factors should be directed to positive future developments for the purpose of reaching high savings. Hence, there are needed different aspects of varying participants: increasing government support concerning electric mobility and renewable energies, further research of scientists, automotive manufacturers that provide on-board saving applications in their car models and EC drivers with a rising acceptance and utilization of software that motivates an efficient consumption of the existing resources. If these aspects are implemented in future, sustainable mobility is reachable in a long-term perspective.