Influence of the Customers Risk Attitude on the Introduction of Electric Vehicles

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Abstract

We present a detailed statistical customer model for Electric Vehicle (EV) owners based on real-world data. An important element in the modeling process is maintaining the customer's mobility service. More specifically we design a customer model that simulates both the individual household consumption and the particular driving characteristics, with high precision. Furthermore, we integrate in the model the customers' risk attitude towards range anxiety. We prove that there exist economic benefits for the individuals who are more risk taking compared to the risk averse ones. Therefore, there are incentives for the customers to adopt more risky attitudes towards *range anxiety*. Apart from that we show that this attitude leads to social welfare improvement in terms of individual savings (on the annual electricity bill). Finally, we examine the effect of the EV penetration rate on the social welfare, assuming different risk attitudes scenarios.

1 Introduction

The fundamental changes in energy policy (such as in California, Germany and Japan) lead to a large integration of renewable energy sources. These sources are highly volatile and necessitate effective balancing on the energy grid to avoid outages. Electric Vehicles (EVs) comprise a valuable tool towards a sustainable solution, since they have storage features. Massive EV integration in the Energy Grid has been outlined by the main players in the energy policy landscape: according to US president's energy plan 1 million EVs are to be integrated in the US energy market by 2020, similar aspirations have been expressed by the German, Dutch and UK governments. The uncoordinated use of EVs, though, will lead to high price peaks during the charging time. Specifically, considering customers *range anxiety* this charging may threaten the grid's stability. Thus, we examine the effect of the EV penetration in the light of the various risk attitudes towards *range anxiety*.

2 Model Description

We propose a customer model for the EV owners which reflects their actual behavior. Our approach is developed as part of the *Energy Informatics* as defined in [5]. We base our simulation on Smart

Electricity Markets as discussed by [1] (phase 1 and 2) and planning to integrate it in the Power TAC environment [3]. An important factor in modeling the EV owners is their driving profile. This profile directly determines the battery capacity that a customer needs for driving and consequently the capacity available to offset supply-demand imbalances. For the precise creation of the customers' driving profiles we use mobility data from the Dutch Statistics Office(CBS)[1]. The population is divided according to gender and the social groups that comprise the total population. Those social groups with their special characteristics are: people younger than 15 years, part-time employees, full-time employees, students and pupils, unemployed, disabled and retired persons. Here full-time employees are considered those who are working 30 hours per week or more, whereas part-time employees are those with 12-30 hours of work per week. For each group there are different activities accompanied with the kilometers needed per day for each activity.

Second step in the modeling process is the day determination (weekday or weekend). Having determined the activities related to each group considering the day, we create driving profiles corresponding to the distance that each customer drives per day (assuming average driving speed). Additionally, we determine the EV type that the customer owns and consequently the respective storage capacity. We assume that the customers in our population own purely electric cars like Nissan Leaf[2] and Tesla[3] (Table 1). With regard to the customer's charging and discharging availability we assume that the customers can charge their EV's battery when they are not only at home but also at work ("standard" charging with direct billing to the customer), which is nowadays implemented by large businesses in order to encourage their employees to drive "green." On the other hand, the customers can discharge energy from their EV battery when they are at home to cover daily demand at peak hours instead of consuming energy from the grid.

The minimum charge level, the customer expects to have available for unplanned use of the vehicle, expresses customer's risk attitude towards range anxiety. Customers who are risk averse, want their EV fully charged as soon as possible after it's plugged in, and never want the charge to be less than 100% once it's charged. On the other hand totally risk seeking customers expect just the amount needed for planned driving at the times they plan to drive. In other words, they do not expect to use the vehicle for unanticipated driving. Thus, we experiment with populations expressing various risk attitudes.

Table 1: Electric Vehicles specifications.

	Tesla			Nissan Leaf
Battery Capacity (KWh)	40	60	85	24
Distance with full battery (km)	257.6	370.1	563.3	222.5
Charging Time for full battery (h)	12	17.5	23	7

For household consumption we use real world data obtained in collaboration with a European Network Company. These data are referring to household consumption of individuals from all social groups in the Netherlands and refer both to weekdays and weekends. Firstly, we need to define the percentage of the battery that a customer can charge in a 24h horizon. Given that an average person in the Netherlands drives 35km per day on average, less than 50% of the EV's battery is enough to cover the customer's driving needs for more than 2 days (depending on the battery's specifications, Table 1).

[1] www.cbs.nl
[2] www.nissanusa.com/leaf-electric-car/
[3] www.teslamotors.com

3 Results and Discussion

Using this model we simulate large populations of household customers with varying degrees of EV ownership. Being aware that EVs will be incrementally integrated in the energy grid, we conduct experiments with penetration within the range [1%, 100%] and examined the effects to the social welfare in terms of individual savings. In [4] the authors deal with batteries without specifying their use in EVs. However, they propose a charging mechanism that leads to social welfare increase. We take into account driving behavior as part of our model. The first results focus on a population of EV owners that charge up to 100% of their EV battery (risk averse towards *range anxiety*, do not want to face battery shortage during the day). We observe that there is no social welfare improvement in terms of savings for all the energy customers in the market. However, the owners of EVs have maximum savings of 3% at a 1% EV penetration (on average €398 savings on annual basis) (Figure 1). Therefore, there is an incentive for the customers to adopt EVs against the conventional cars, without the government imposing any extra tax or other financial incentives for EV adoption. More specifically, the early adopters even in a totally risk averse population have economic benefits. The saturation point for EV penetration is 16% in a risk averse population. After this point there are no savings for the EV adopters (instead the pay more), so the policy makers should provide incentives for a penetration up to this point for totally risk averse population. However, this is an extreme scenario, since in reality the population is mixed with, in fact, higher percentage of risky seeking individuals [2].

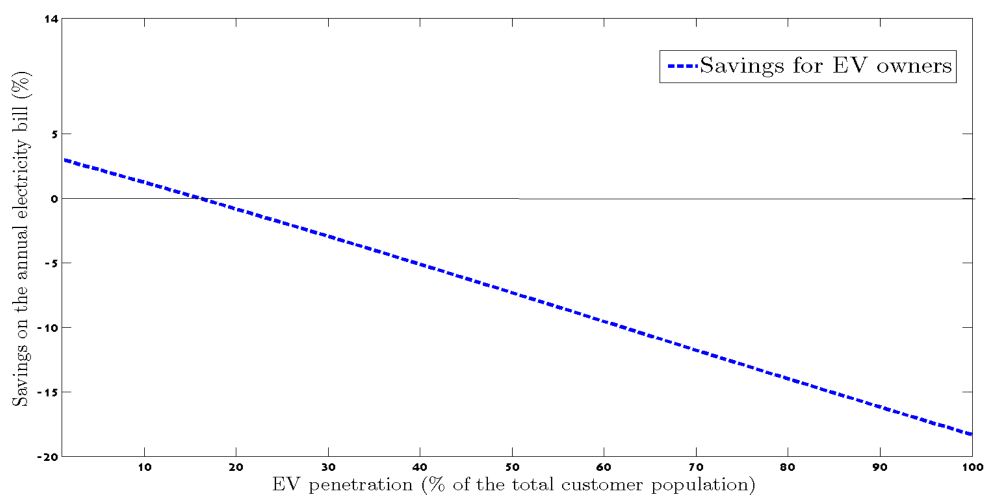


Figure 1: Home energy savings for EV owners as a function of EV penetration in a risk averse population (charging up to full battery).

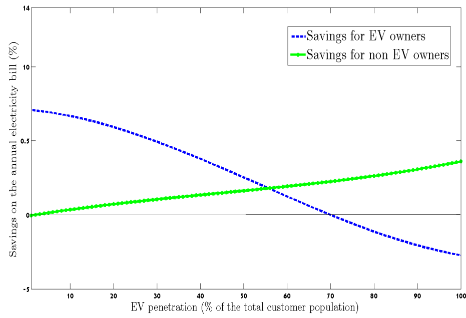
Additionally, we experiment with populations with intermediate risk attitude (charge up to 50%), risk seeking towards risk anxiety (charge up to 20%) and mixed population where all risk attitudes are present. A battery charged to 50% corresponds to driving 111 km for a Nissan Leaf and above 170 km for each Tesla model. This satisfies the driving needs for almost 3 days (the average Dutch customer drives 35km per day). With this attitude we observe that the equilibrium point for savings among EV owners and non-EV owners is at 56% EV penetration yielding savings of 1.8% on the annual electricity bills for all the customers in the market(Figure 2(a)), while the saturation point for EV penetration is 70%. Also we achieve significant social welfare improvement for all the customers in the market, EV owners and non-EV owners (Figure 2(b)). The maximum improvement is for 38% penetration and yields 2.25% savings on the annual electricity bill for each individual, whereas penetration above 78% does not yield any improvement on the social welfare.

Furthermore, for the risk seeking population, 20% of EV battery's nominal capacity, corresponds to 44 km for Nissan Leaf and above 52 km for the Tesla car models (Figure 2(c)). We observe that the equilibrium point for savings among EV owners and non-EV owners is at 96% EV penetration yielding savings of 12.11% on the annual electricity bills for all the customers in the market, while the saturation point for EV penetration is 100%, with savings for EV owners 12.15% and 12.65% for non EV owners (Figure 2(d)). This percentage does not affect customer's driving comfort as it allows for covering his daily driving needs. This yields maximum social welfare improvement 12.08% (Figure 2(e)) for penetration 92%. Consequently, the risk attitude affects the customers savings and the social welfare. Thus, the policy makers should give strong incentives to the customers to adopt risk seeking attitude.

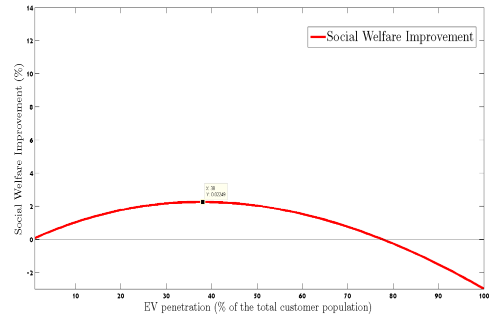
Finally in the mixed scenario there are customers who are risk averse and (in 35% of the population), customers with intermediate risk attitude and want to be sure that their battery covers their driving needs for the next 24h horizon and charge up to 50% of their capacity (in 35% of the population) and customers who are more risk seeking and charge their EV battery up to 20% in order to cover their driving needs only for the next 24h horizon (in 30% of the population). The choice of the percentages is based on Kahneman's theory that people are more risk averse than risk seeking [2]. This scenario reflects reality with all different attitudes towards *range anxiety* (Figure 2(f)). The equilibrium point for savings among EV owners and non-EV owners is at 74% EV penetration yielding savings of 2.5% on the annual bills for all the customers in the market, while the saturation point for EV penetration is 100%, with savings for EV onwers 0.4% and 35.77% for non EV owners. Also, this scenario yields maximum social welfare improvement 2.84% (Figure 7) for penetration 56%.

4 Conclusions and Future Work

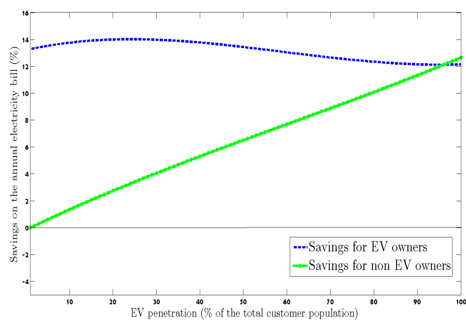
We presented a realistic EV customer model that models every particular daily activity of each social group and the exact kilometers needed per activity. Secondly, we expressed the risk attitude of the customers towards *range anxiety*. Finally, we showed that more risky attitudes towards range anxiety improve the social welfare, ensuring bill savings for each individual. We experimented with EV penetrations and examined their effect on the social welfare improvement. Our next step is to design incentives for selling the capacity back to the grid instead of consuming it, under various pricing schemes. This behavior will have different effect on the social welfare improvement and the individual savings. Furthermore, we will design Demand Response programs for EV owners and examine their impact on the energy demand and prices.



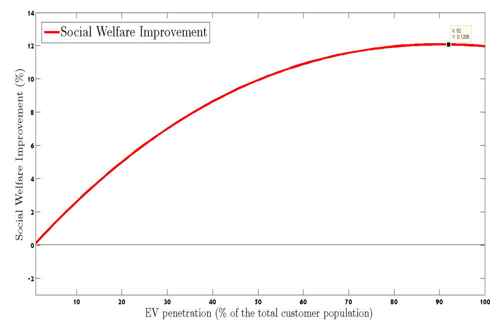
(a) Home energy savings for EV owners and non EV owners as a function of EV penetration in a population with intermediate risk attitude (charging up to 50% battery).



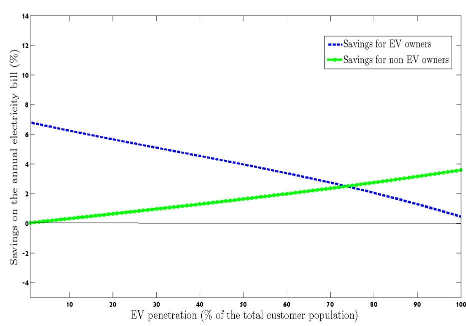
(b) Social welfare improvement in a population with intermediate risk attitude (charging up to 50% battery).



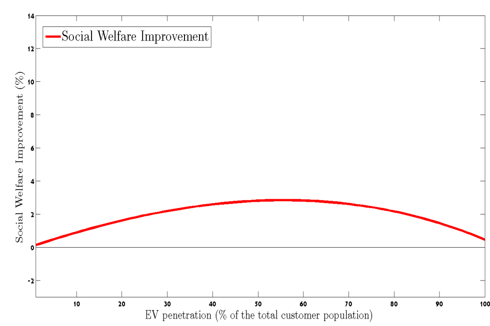
(c) Home energy savings for EV owners and non EV owners as a function of EV penetration in a risk seeking population (charging up to 20% battery).



(d) Social welfare improvement in a risk seeking population (charging up to 20% battery).



(e) Home energy savings for EV owners and non EV owners as a function of EV penetration in a mixed risk attitude population.



(f) Social welfare improvement in a mixed risk attitude population depending on the Electric Vehicle penetration.

Figure 2: Home energy savings and social welfare improvement for populations with varying risk attitude towards *range anxiety* ((a), (b), (c), (d), (e) and (f)).

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