Assessing the competitiveness of electric vehicles for last mile deliveries

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Electric vehicles (EVs) differ on many aspects from Internal Combustion Engine Vehicles (ICEVs), and are therefore not perfectly substitutable. Some positive differences are the environmental performance or the improved driving comfort, and on the contrary other characteristics can hold potential users from switching to EVs, like limited range and necessity for charging. The aim of the project is to evaluate how these different characteristics affect the competitiveness of electric vehicles. To do that, two specific points must be kept in mind. First, as the level of potential or inconvenience of EVs depends on the precise uses, the competitiveness must be assessed while taking into account their diversity. On the other hand, the context around electric vehicles is in permanent evolution, and this must be anticipated. Indeed, the impact may be sometimes positive for EVs (fast technologic improvements), sometimes negative (reduction of the incentives).

Investigating range and costs through a simplified decision model

The work that has been done aimed at evaluating two characteristics of EVs, while taking into account the two previously stated points: a significant variability of the uses, and a moving and uncertain context. These two characteristics are the limited range of EVs, and their Total Cost of Ownership (TCO), as opposed to ICEVs. This is of course a rough estimation of the competitiveness of EVs: many other **operational factors** can be affecting their use, among which the access to a charging infrastructure may be among the most critical factors. The simplification of the **economic performance** to the TCO can as well be discussed, as companies may not always take the time to compute it to compare the technologies. This approach also ignores the **cognitive factors**, like the inertia of the organizations or the attitude towards EVs, and the **regulatory factors** as well, as the interdiction of the most polluting vehicles in city centers.

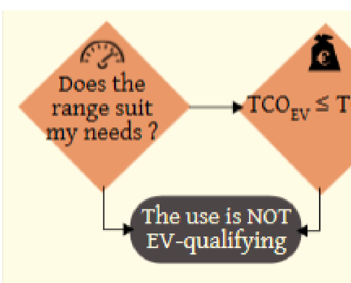
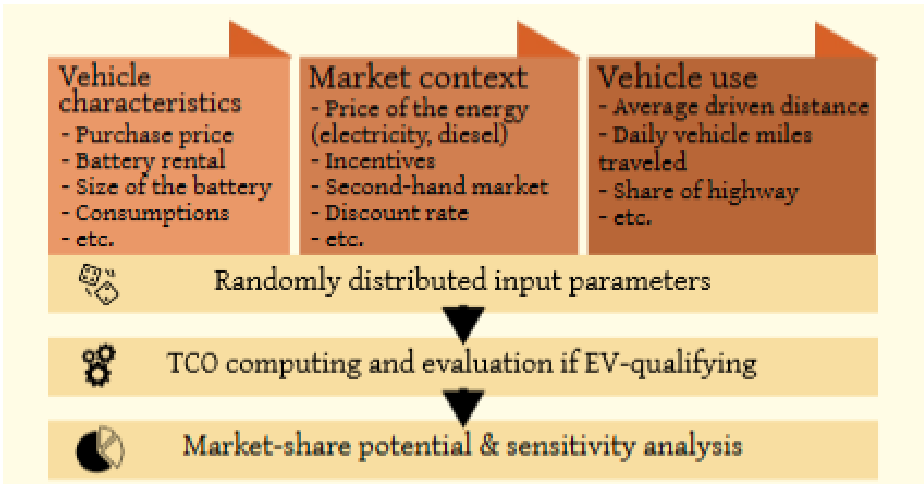


FIG 2. Simplified decision process to discriminate EV-qualifying vehicles
Assumption: overnight charging

However, range and TCO are among the most blocking and shared constraints, and are interesting to investigate as they represent an equilibrium between two opposite forces: If the battery is bigger, then the range is extended, but the purchase costs are increased, and oppositely. Fig. 2 shows the simplified decision model we used for this study.

A stochastic model to cope with volatile parameters and individual variability



The use of a stochastic model enables us to deal with both volatile parameters and individual variability. Indeed, statistical distributions of the future market context (incentives, fuel prices…) correspond to odds making, given the currently known information, and individual use variability distributions are fitted upon past observed distributions.

Repeating a large number of times the decision model with randomly distributed input parameters enables us to give a proxy for a potential market share: the number of EV-qualifying vehicles among the number of vehicles tested. This potential is in fact, when projecting inputs in the future, a mathematical expectation of the market share, given the uncertainties of the inputs.

Dealing with sparse data

One specific difficulty to set up this model is the lack of input data. Indeed, the inconvenience of the limited range is often given by the number of days at which the range is exceeded. Only, the longest trips may be rare, and therefore hard to grasp, for example with GPS data. Long-time GPS recordings would indeed be necessary. Direct surveys to the drivers sometimes give the maximum daily driven distance, but don’t enable us to measure the number of inconvenience days that ensue of the limited range.

We chose to model the Daily Vehicle Miles Traveled (DVMT) variations. The model is then fitted to the marginal data using an optimization algorithm.

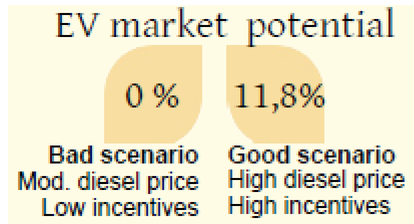
This modeling gives interesting results, but two points need further investigation: the first one is the validity of the model for Light Commercial Vehicles, when it has exclusively been used for private cars until now. The second is the assessment of confidence intervals, to indicate the precision that can be expected with such modeling.

Some results raised by the model

The model has been run with input data corresponding to the small van market in France (less than 2 tons gross weight), with market prices corresponding to the 2016 prices, and a projection to 2021. The inputs will not be discussed in detail here, but can be found in the corresponding TRB publication.

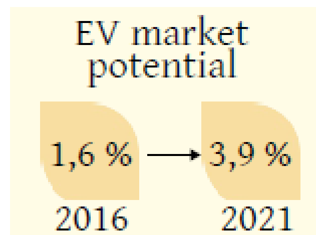
A high sensitivity to the input parameters

One of the first results is the high sensitivity of the results to the inputs. Indeed, diesel price and incentives can drive or put to a stop the electric vehicle market. To validate this, a further step would be to correlate the actual current economic contexts of several countries, and to see the correlation with the market share of electric vehicles. Norway may be of special interest, as it is the first electric vehicle market in Europe, with a big support to the market.



An increasing market share but no exponential growth

A second result, despite this sensitivity, is that a modest increase in EV market potential between 2016 and 2021 (of around 2.3 points) can be expected. As innovations have often an exponential growth, as given by the innovation theory's S-shaped diffusion curve, here we observe that it is likely that the drop in incentives counterbalances diffusion and technological progress. Incentives dynamics present a negative feedback: if the sales rise, the incentives are likely to drop, damping the market dynamics.



However, other growth drivers can be identified, which could point toward an underestimation of future potentials in the previous figures. The first one is linked to the diversity of the offer.

A diversification of the offer

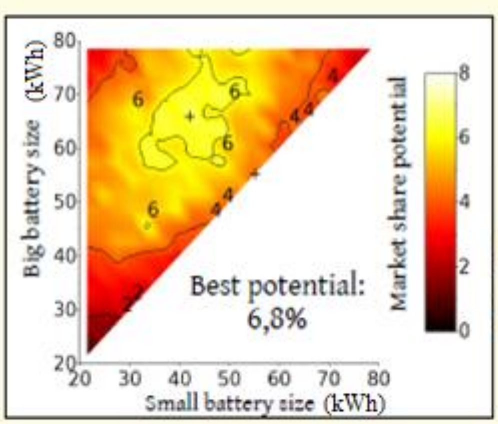


FIG 4. EV Potential market share if the customers can choose between two battery sizes

[42 kWh, 66 kWh] with a 74% potential increase compared to a single battery size.

Indeed, while today the price of batteries is pressuring towards smaller batteries (bigger batteries do not meet any users' economic equation), the drop in battery prices will allow a diversification of the offer in battery sizes. And we see that different batteries can suit different users, as the offer of two batteries can bring, according to the models' results, 2.9 additional points to the market share potential, bringing it to 6.8%.

Alternatives for out-of-range trips can boost the EV-potential

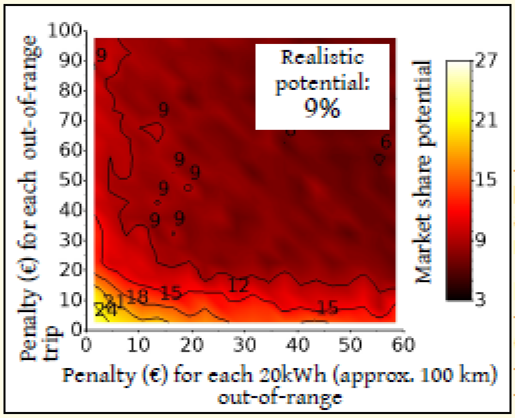


FIG 6. EV Potential market share with the range constraint replaced by a monetary penalization

- EV performs much better when there exists alternatives for out-of-range trips.

Possible alternatives are :
- a mixed ICEV / EV fleet (very promising)
- a vehicle rental
- quick charging

At last, if we replace the range constraint with a monetary penalization for out-of-range trips or out-of-range consumption, we observe that even if they have to be paid for, the existence of alternatives enables the use of electric vehicles for even a wider range of users, with a realistic EV market share potential between 6% and 9% (depending on the amount of penalization). Some of the possible alternatives are mixed ICEV / EV fleet, renting a vehicle, or quick charging along the way.

Conclusion

The model has been applied to the French van market. Even if a drop in battery prices does not necessarily lead to an exponential rise in market shares (because of reduced financial incentives), a moderate gain in competitiveness is to be expected. However, a more diversified offer in battery sizes together with alternatives for long distance trips can multiply this potential. This means both that the alternative be widely available (e.g. fast charging) and that it be accepted by the user.

Next steps

The next steps of this research are more qualitative. Research trips are planned to Germany, Norway and Sweden, to have interviews with professional associations, fleet managers and vehicle users. The aim is to investigate how they perceive the constraints and opportunities of EVs, and to evaluate their attitude towards electric vehicles. This will allow us to explore the impact of cognitive factors and regulatory factors on the competitiveness of EVs a bit further into details, and confirm or shed some light on the underlying assumptions of the model, like the relevance of using Total Cost of Ownership for the economic performance.

A second progression axis is on the validation of the model, which can be a mathematical validation and/or a validation on real longitudinal GPS data. Once validated, further results could be analyzed, on different markets. Three clustering possibilities seem interesting: clusters according to countries and corresponding contexts, clusters according to vehicle size, and clusters according to business activity.