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Hydrogen and/ or Battery Electric Vehicles – Where Will Development Go To?

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1 Background

The private transport sector is worldwide primarily based on the use of fossil fuels. Utilisation of these fuels causes a lot of emissions, including the greenhouse gas CO_2 and pollutants like particulate matter, nitrogen oxide, hydrocarbons etc. As a result of the emission of greenhouse gases the impacts of climate change are intensified. The other pollutants have various negative impacts on human health, flora and fauna. In 2005 the whole transport sector emitted over 6.3 Gt of CO_2, which is equivalent to 23 percent of the total global energy-related CO_2-emissions [1]. Light duty vehicles caused over 2.7 Gt of CO_2-emissions [2]; therefore they were responsible for around 10 percent of global energy-related CO_2-emissions. Like in other CO_2-emitting sectors a reduction of emissions is necessary for limitation of global warming. The worldwide increasing number of cars and thereby driven distances makes the challenge to lower emissions in this sector to a huge technical and political challenge.

In consequence of the growing consumption of fossil fuels, car drivers were faced with increasing fuel costs during the last years. As an effect of this and due to an increased environmental sensibility in general and especially on account of the climate change discussion, alternative fuels and drive concepts became much more important in the public interest.

Beside others the before mentioned factors led to changes of the whole road transportation system. Indicators for this development are the increasing use of biofuels and hybrid cars as well as an even smaller but also growing number of battery electric and fuel cell vehicles. In the future technological changes will be even more far-reaching.

2 Introduction and Research Question

Actual many kinds of alternative powertrains are in development, which will have stakes on the market for private used cars in the next years. Departing from this middle-term perspective, long-term strategies of automobile manufacturers (produced cars after 2020/2030) are primarily focused on only two of them: Fuel cell vehicles as a kind of hydrogen cars and battery electric vehicles.

By now there is a large disagreement in the political and public discussion, if both technologies will coexist in the future, or if only one will remain in the end.

This poster presentation deals with this subject and it tries to reach clarification in these discussions, by pointing out:

- The central factors of influence on the private transport market
- The main differences between battery electric and fuel cell vehicles

In this context the market introduction of fuel cell and battery electric vehicles is analysed in a comparative way.

In focus of the analysis is the car buyers' point of view (customer perspective). The main questions out of this perspective are: What are the expectations and requirements of the car buyer? And: Can the different car types meet these requirements in the future?

The car buyer's perspective has been chosen, because the buyer, as market participant, has an essential impact on the future demand of private vehicles and is therefore a determining factor for the market development.

3 Method

To get a clear view, how the both assayed car types can meet different decision criteria of car buyers, at first the whole private transport sector is separated into different segments. The chosen segmentation points out differences in the use of cars (travelled distance) depending on the engine output. As a result of these statistics a detailed pattern of car utilisation in the private transport sector is shown.

The next step is a meta-analysis of surveys, concerning determining factors on the car buyers' decisions to buy a new and alternative type of car.

Based on the identified criteria, fuel cell and battery electric vehicle are compared.

To evaluate the two car types from the car buyers' point of view, the requirements and use patterns are checked against the actual and future technological development status of both car types. Values for the car buyers' requirements are taken, if listed in the before mentioned surveys. Otherwise actual average values for each criterion are used for the comparison. Also the spread of the actual and future technological development status is shown.

Because of the variety of boundary conditions some assumptions and simplifications are used:

Other alternative forms of public mobility (e.g. cars using biofuels, hybrids, battery electric vehicle with range extender) are not part of this analysis.

Statistical data for Germany are used, which reflect the typical car utilisation in Germany. In other countries the car utilisation could be completely different.

A further simplification is the consideration, that driven kilometres and the private car equipment will be the same in the future.

Also forms of political influence are not integrated in this analysis.

The characteristics of the battery electric vehicles are constrained on lithium-ion batteries because they offer the best combination of power and energy density and the biggest amount of research promotion for batteries.

For fuel costs it is considered, that in future perspectives hydrogen and electricity for driving purposes will completely be produced from renewable resources.

4 Results

The segmentation concerning the engine output shows that more than half of all cars between 15 and 400 kilowatts are located between 50 and 79 kW [3]. The daily or yearly driven distance increases in general with incremental engine output. The daily data is

calculated on the basis of the average of yearly driven kilometres for each engine output class [3] and the assumption, that the car is used on 350 days in a year. In result the yearly and daily driven kilometres are 60 percent higher for cars with engine outputs between 100 and 400 kW as in those with 15 to 49 kW.

Also second and third cars of households are analysed concerning their patterns of utilisation. The percental share of different distances in all travelled ways of first, second and third cars are compared. For the German example the shares are nearly the same. Despite it is probably, that the whole amount of driven distance is different, but there is no data available to confirm this.

Many recently published surveys concerning the determining factors on the car buyers' decisions to buy a new and alternative car (e.g. [4, 5, 6, 7, 8, 9, 10, 11]) are part of a meta-analysis. The surveys are analysed by picking out the criteria, which are mentioned the most times or with the highest rates of importance in the decision for or against buying a new and alternative car. Following key factors are identified:

- Purchase costs
- Fuel costs
- Range
- Refuelling time

The purchasing decision also depends on other aspects like safety, design and the image that is connected to the car, but they seem to play a minor part and are not considered further.

The general results of the comparison of battery electric and fuel cell vehicles are listed below. Advantages of battery electric vehicles especially appear in the actual purchasing costs and their fuel costs. Today battery electric vehicles cost mostly between double and triple the price, in comparison with a conventional car. The range of estimated costs for current fuel cell vehicles fluctuates broadly. A reason for this is the small number of produced cars (only prototypes), which are, in contrary to battery electric vehicles, not available to the market right now. The predicted purchase costs for fuel cell vehicles are actually significantly higher. The energy consumption inside the battery electric vehicle, as well as the production and distribution is more energy efficient, than it is for fuel cell vehicles and the hydrogen production and distribution. This effect lowers fuel costs for battery electric cars, which also will remain on a lower level in the future. On the other hand fuel cell vehicles meet the requirements towards range and refuelling time in a better way. The charging time of the battery electric vehicles has a broad range because there are a lot of different technical concepts. The car could be charged with usual power level, high power or inductive. Another possibility would be a change of the used battery against a charged one. Options with fast refuelling times (high power charging and change of batteries) would be better accepted from car buyers, but up to now they cause some problems, like shorter life time and different battery quality. The time of refuelling fuel cell vehicles doesn't clearly differ from the time to refuel conventional cars, what means a clear advantage for this car type today and probably also in the future. Another advantage of fuel cell vehicles is given by meeting range requirements of the car buyers. In future the range of fuel cell vehicles could nearly be on the level of actual conventional cars. On the other hand the possible range of battery electric

vehicle will certainly increase, but under real driving conditions these vehicles won't be able to reach the ranges, that actual cars do.

Based on the accomplished segmentation and the considered car buyers' key criteria, the comparison, answering the central question of this study, shows, that not only one car type appears to be completely advantageous. Strength and weakness of the cars are very dependent of their end-use. Battery electric vehicles become advantageous for patterns of utilisation of smaller cars (cars with less engine output), which are used in cities. Fuel cell vehicles meet the demands concerning the four main criteria in higher vehicle classes better, which are primarily used as the first car of households and travel longer distances.

As an effect both car types will coexist. But there will be different emphases in the segments. These aspects show, that it is extremely important to handle the results in a differentiated way.

Successful research for one of these technologies could also have a positive effect on the other technology. One example is the research on batteries for driving purposes. Fuel cell vehicles as well as battery electric vehicles use batteries, for which reason the research on batteries will have positive economic and technological effects on both technology pathways.

5 Further Requirement of Research

As a conclusion, future research and development for battery electric and fuel cell vehicles should not only be focused on technological progress (supply-side). It is also important to find out, which political support and which business model should be used for different market segments to cause the most effective development at the right time (demand-side).

This is closely linked to the question, how to build up the hydrogen and charging infrastructure in a combined and economic as well as ecological optimal way.

Additional to the results of the comparison of battery electric vehicles and fuel cell vehicles in this study, some general aspects should be mentioned.

It is possible, that the patterns of the mobility utilisation could change in terms of significantly more or less distance travelled with private cars and via a growing use of public transport and carsharing. As an effect, range requirements towards private cars could decrease and battery electric vehicle could become more interesting. This leads to the research task, to monitor patterns of car utilisation and car buyers' expectations by statistics and surveys.

In this study a gap of information about these types of future cars and between the car buyers' real mobility demand and what is expected from the car is identified. There is a need for a lot of information work in the future. Especially the integrated view is still missing in the car buyers' considerations. Examples are total cost of ownership over the whole lifetime and the consideration of consumption by doing a well-to-wheel-analysis.

Contrary to the patterns of utilisation in Germany the private car use in many other countries in the world is on a significantly lower level. In these countries the individual mobility with cars will start and be especially focussed in the cities, so range requirements will be lower and battery electric vehicles could probably have a higher market share than fuel cell vehicles. This will give a lot of scientists the opportunity to implement individual market analyses for different regions.

For both car types technological development has to enhance criteria like range, refuelling time, and the efficiency of the energy use as well as life time, infrastructure, safety, variety of design, materials, weight etc. But the most important fact is two lower the price of those cars to enhance the car buyers' interest and desire. In addition there are many political possibilities to make these car types more interesting for customers in the coming years. Some instruments might be: Support of R&D, CO_2 tax, tax concessions, buy promotion, ability to use environmental zones with entry restrictions.

Furthermore there are many new business models for car manufacturers, power supply companies and mobility providers possible, which could be an interesting alternative to the old model of purchasing the whole car and paying for each litre of fuel.

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