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On the economic prospects of alternative powertrains in car transport

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Abstract:
Passenger cars are one of the largest producers of carbon dioxide. These emissions could be significantly reduced with the increasing use of alternative powertrains. However, alternative technologies especially battery electric vehicles and fuel cell cars are currently very expensive and not competitive with conventional cars.
This paper investigates the long-term prospects of environmental friendly alternative powertrains in a dynamic framework up to 2050 for average conditions of EU-15 countries. We conduct a dynamic technical and economic analysis and investigate when in the future these vehicles could become – under favorable conditions – economically competitive. To evaluate the economics we calculate the transport service costs per 100 kilometers driven.
The major conclusions of this analysis are: With respect to the economic competitiveness of alternative powertrains compared to conventional vehicles in the most favorable case (long distance driven cars) battery electric vehicles will enter the market by about 2025. Fuel cell vehicles powered by hydrogen will become competitive later, by about 2040. However, the major uncertainty is technological learning especially in the case of batteries and fuel cells.

Keywords: *Economics; hydrogen; electricity; transport*

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1. Introduction

Road transport contributes to about one-fifth of the EU's total emissions of carbon dioxide (CO_2) and is the second biggest source of greenhouse gas emissions (GHG) in the EU. These emissions are continuously increasing over the last decades, mostly due to increasing travel activity, size and number of passenger cars. A switch to more environmental friendly vehicles such as zero-emission vehicles is of a high priority.

There is widespread agreement that new alternative powertrains – especially battery electric vehicles (BEV), hybrid electric vehicles (HEV) and hydrogen-powered fuel cell vehicles (FCV) – are able to increase use of renewable energy in transport. They are considered as important environmentally benign alternatives to conventional cars powered with fossil fuels. However, high investment costs (IC) are still a major barrier for their broader market penetration.

This paper investigates the long-term prospects of these alternative powertrains in a dynamic framework up to 2050 for average conditions of EU-15 countries. This work builds on Ajanovic et al (2011) and Ajanovic et al (2013).

2. Method of approach

Our method of approach is based on a scenario up to 2050. We conduct a dynamic technical and economic analysis and investigate when in the future HEV, BEV and FCV could become – under favorable conditions – economically competitive compared to conventional cars. To evaluate the economics we compare the transport service costs per 100 kilometers driven (C_{km}). In this context different average driving distances (skm) per car and year play a significant role. Transport service costs are calculated as in Eq. (1):

$$C_{km} = \frac{IC \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O\&M}}{skm} \qquad \text{[€/100 km driven]} \qquad (1)$$

where α is capital recovery factor; P_f is fuel price incl. taxes [€/litre]; $C_{O\&M}$ are operating and maintenance costs.

In the economic analysis we also consider the potential effects of CO_2 taxes which are included in fuel price (P_f). For cars' fuel intensities (FI) the historical developments and future assumptions up to 2050 (for a car size of 80 kW) are described in Fig. 1. Note that the steepest decrease in fuel intensities took place already before 2011 as a first result of the European Commission efforts to improve the efficiency of car fleets.

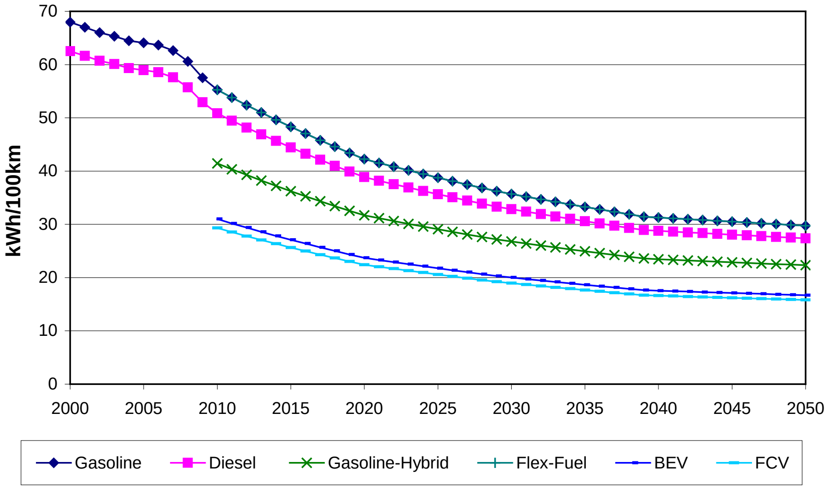

Fig. 1 Historical developments of cars' fuel intensities and assumptions for development in a BAU scenario up to 2050 (car size: 80 kW) (based on: Kobayashi et al., 2009; Toro et al., 2010; EC, 2010; CO_2 database, 2009; CONCAWE, 2008).

To capture the dynamic effects of changes in investment costs of powertrains over time we apply the approach of technological learning. For new technology components ($IC_{New\_t}(x)$) we use Eq. (2) to express an experience curve by using an exponential regression:

$$IC_{New\_t}(x) = a \cdot x_t^{-b} \qquad [€/kW] \qquad (2)$$

where b is a learning index, and a are the investment cost of the first unit.

Fig. 2 shows the stock of cars in the scenario for world-wide market diffusion of HEV, BEV and FCV, based on IEA (2011).

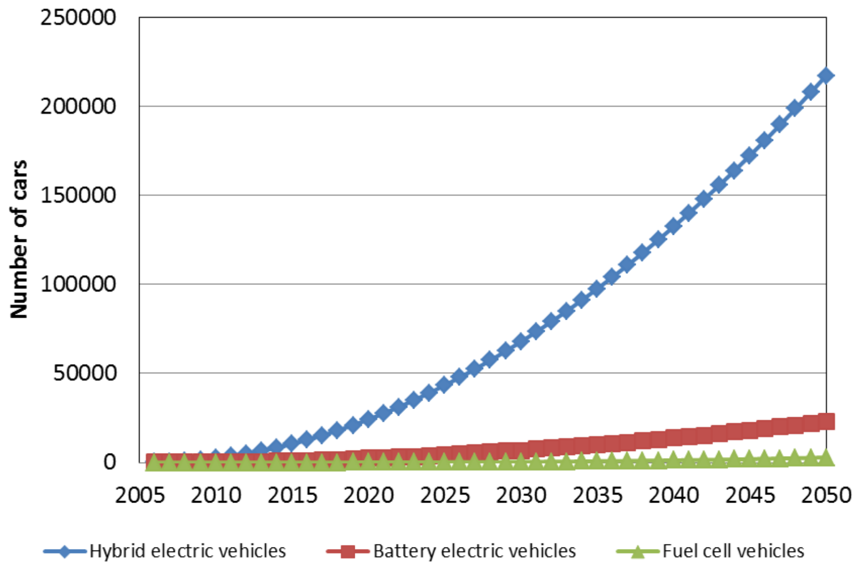

Fig. 2 Scenarios for world-wide market diffusion of HEV, BEV and FCV 2012-2050.

Since the investment costs of alternative powertrains are currently very high, increasing use of BEV and FCV will be possible in the first stage with supporting policy measures and later with the cost reduction due to technological learning and mass production.

Fig. 3 illustrates the developments of the investment costs of the considered powertrains by 2050. Of course, the most remarkable cost decreases are expected for BEV and FCV.

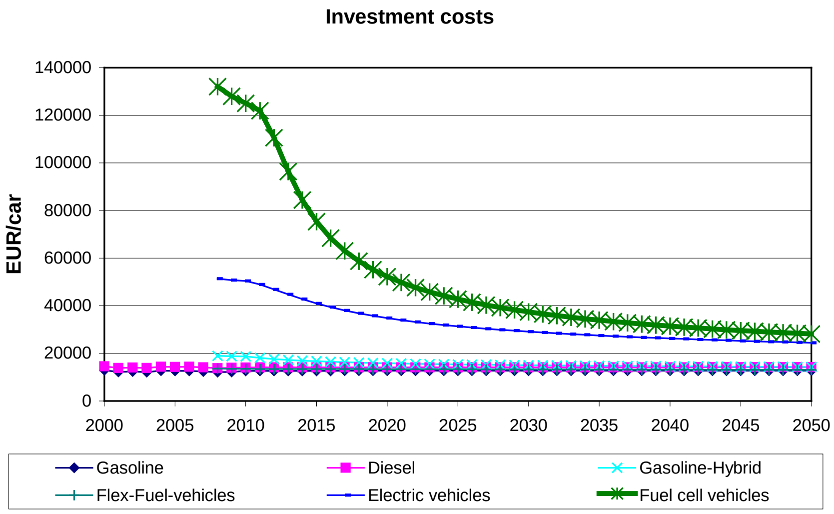

Fig. 3 Development of investment costs of the considered powertrains over time considering technological learning and service increases.

3. Results and discussion

The specific capital costs have the largest impact on the driving costs especially in the case of new alternative powertrains. However, these costs can be reduced in the future based on technical improvement potentials as shown in Fig. 3.

Finally, Fig. 4 compares the development of the total costs of service mobility per 100 km driven of different types of passenger cars. The total costs for conventional cars will increase slightly in the future– mainly because of the higher taxation and resulting increase in fuel costs – while driving costs of BEV and FCV will decrease significantly due to technological learning. By 2050 costs of most of cars will even out, see Fig 4. However, a paradox is that economics of alternative powertrains increases with number of km driven per car and year.

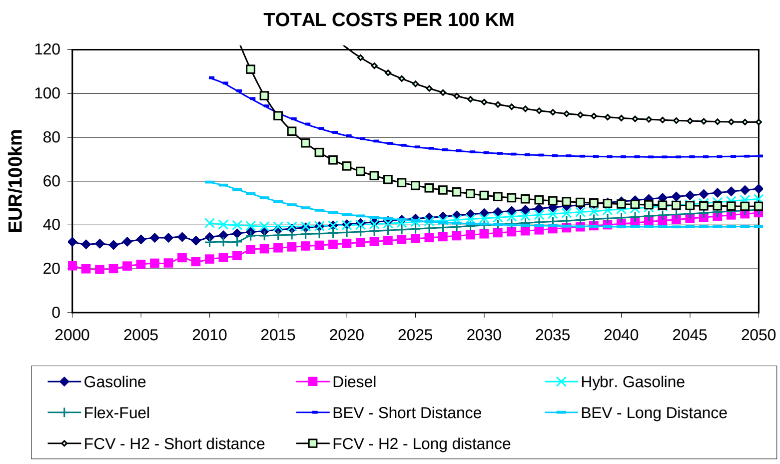

Fig. 4 Development of total costs of service mobility per 100 km driven of different types of passenger cars in 2000- 2050.

4. Conclusions

The major conclusions of this analysis are: With respect to the economic competitiveness of alternative powertrains compared to conventional vehicles in the most favourable case (long distance driven cars) BEV will enter the market by about 2025. FCV will become competitive even later, by about 2040. The major uncertainty remaining regarding BEV and FCV is how fast technological learning will take place especially for the battery and the fuel cells.

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