ON THE ENERGY ECONOMICS OF GREEN HYDROGEN FOR DRIVING FUEL CELL PASSENGER CARS

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Overview

Among the energy carriers, hydrogen is most often named as a future energy carrier for a sustainable energy system. Over the last years, the use of variable renewable energy sources (RES) for electricity generation has led to new challenges like rising imbalances between electricity generation and load as illustrated in Fig. 1 for the example of Austria over the months of a year. The graph shows a hypothetical situation with a high quantity of variable electricity production using monitored hourly data. With the upgoing electricity generation from photovoltaics and wind, also larger quantities of temporarily cheap excess electricity could become available, see e.g. [1,2]. Hydrogen could be one of the storage opportunities to meet the challenge of evening out this imbalance.

In order to avoid re-electrification losses, hydrogen can be used as a fuel in the transport sector, see [3-5]. Transport is still the end use sector with continuously increasing emissions and low energy efficiency. At least since the early 2000s efforts are under way to make passenger cars more environmentally benign and more energy efficient. In this context of special interest are alternative powertrains like battery electric vehicles (BEVs) and hydrogen-based fuel cell vehicles (FCVs). However, FCVs are still substantially more expensive than conventional combustion engine vehicles and this is one of the major barriers for their broader market penetration. Currently, hydrogen use in the transport sector is virtually neglectable.

The core objective of this paper is to investigate the energy economic prospects of hydrogen in passenger car transport in Europe and to analyze the future market prospects in a dynamic framework up to 2050 in comparison to conventional passenger cars for average conditions of EU-15 countries.

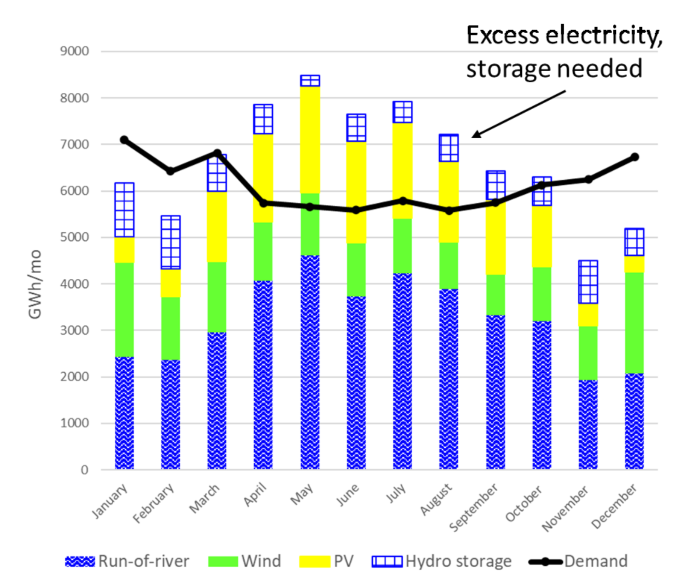

Fig. 1. Distribution of electricity generation from variable RES as PV, wind and run-of-river hydro power as well as load (demand) over the months for the example of Austria

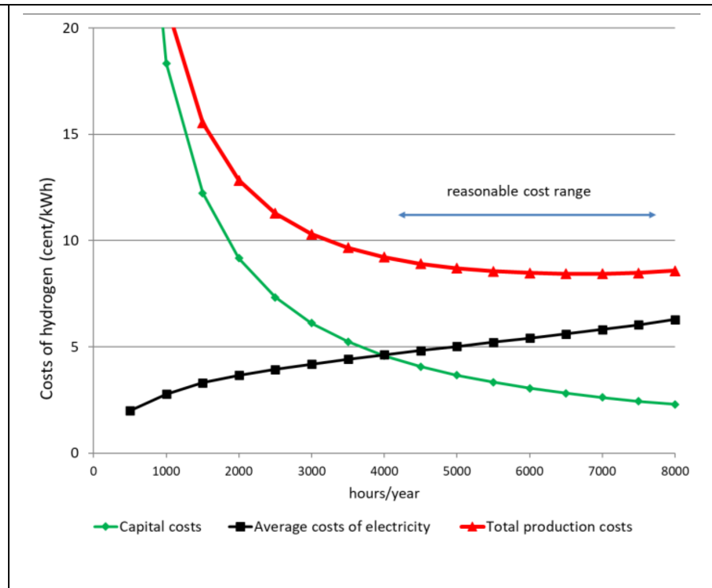

Fig. 2. Production costs of hydrogen via electrolyzer depending on the full-load hours

Method

For the analysis of the costs of hydrogen we use the investment costs of electrolyzer, the full-load hours and the electricity costs. Figure 2 shows the corresponding production costs of hydrogen produced via electrolyzer depending on the full-load hours. For the economic analyses in passenger car transport we consider investment costs (IC) of vehicles, operating and maintenance costs ($C_{O\&M}$), specific number of kilometres driven per car per year (skm), the energy/fuel price (P_f), and specific energy consumption (FI). Our formal economic framework starts with calculating the total driving costs (C_{drive}) per year (all cost values in this paper refer to EUROs of 2020):

$$C_{drive} = IC\,\alpha + P_f FI\ skm + C_{O\&M} \quad [€/car/year] \qquad (1)$$

Results

The most important results are: (i) Figure 3 shows a comparison of the cost structure of total costs of driving for different types of cars in 2020. It can be noticed that FCVs have significantly higher total driving costs in comparison to other automotive technologies mostly due to high investment costs. Nevertheless, FCVs are widely discussed as an alternative to BEVs when longer driving ranges and faster refueling times are needed; (ii) In the long run BEVs and FCVs will remain the most environmentally benign options especially in the case that electricits and hydrogen are produced from the RES. These vehicles benefit from every carbon pricing strategy; (iii) The major uncertainty regarding BEVs and FCVs is how fast cost reduction due to technological learning will take place especially for batteries and fuel cells, see Fig. 4. Yet, as can be seen from this figure, so far already significant learning effects took place; (iv) Finally, CO_2 costs (e.g. taxation) will play a crucial role for the final future fuel mix.

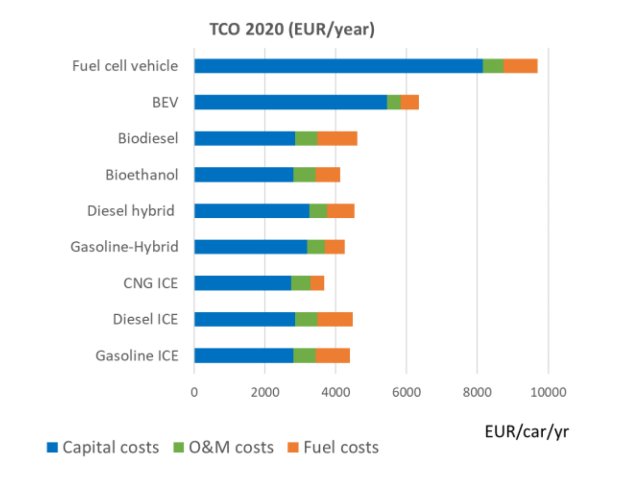

Fig. 3. Total costs of driving passenger cars per year in 2020 (Average car capacity: 80 kW, different driving ranges based on historical experience)

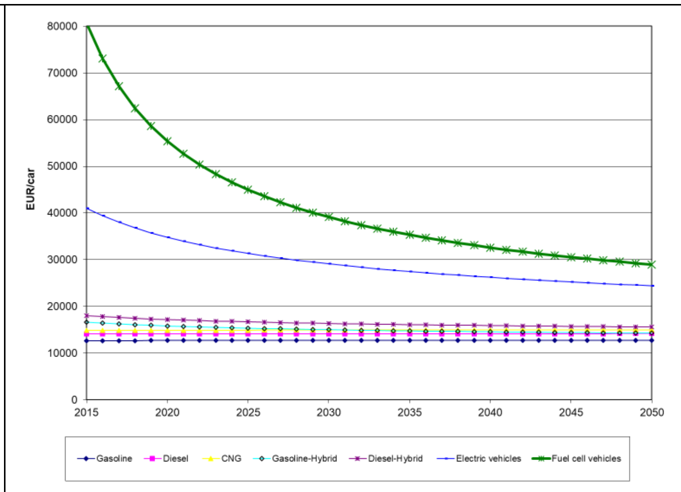

Fig. 4. Development of investment costs of the considered powertrains over time considering technological learning 2015 -2050

Conclusions

The major conclusions of this analysis are:

- The way towards a sustainable passenger car mobility system has to be accompanied by rigorous policy measures promoting zero-emission vehicles;
- In the future, fuel cell vehicles could play a significant role only if the proper mix of policy measures (e.g. CO_2-taxes and non-monetary incentives) are implemented timely, as well as due to intensified R&D and corresponding riding down the learning curve of fuel cells;
- Moreover, the ban of diesel and petrol vehicles as already announced in different countries could significantly accelerate the use of FCVs.

References

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