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On the competitiveness of electric driving in France: Impact of driving patterns

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ABSTRACT

The environmental issues in the transport sector are numerous and CO_2 capture is not even plausible for vehicles at the moment. This report describes a number of different emergent power train technologies (ICE, BEV, PHEV, FCEV) before providing an inter-comparison of these technologies within a technical and economic context.

The economical benefits are discussed in terms of the “Difference of Total Cost of Ownership” (DTCO) and take: electric driving distances, energy (fuel, electricity, hydrogen) prices, batteries and fuel cells costs. To simulate electric driving distances, the model uses several functional parameters such as the battery range and the ‘range anxiety’ based on the assumption of one recharge per day. The potential electric driving distances are evaluated according to the segmentation statistics of daily trips.

The results show the yearly mileages, as well as the range and cost of batteries and fuel cells, together with their relative impact on the DTCO and on the competitiveness of electric vehicles. The price of electric vehicles remains high with strong dependency on the battery's capacity, but the benefits in terms of fuel cost savings can be considerable. The price of electricity is currently noticeably lower than petroleum-based fuels, which balances the high costs of the batteries. 50% or more of LDV yearly mileages can be electric-driven, even for limited battery ranges (ca. under 50 km). There are stakes for the battery costs (competitiveness under €215/kWh) and lifetimes, while the low battery ranges (100 km in our case) provide the best margins.

As regards FCEVs, the hydrogen target price at the pump should be achievable (less than €6.5/kg) with reasonable gasoline prices (€1.7/liter at the pump) and fuel cell costs (€20/kW). CO_2 taxes and ICE efficiency gains will lead to opposite impacts of the H_2 target prices at the pump.

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1. Introduction

In 2010, the IEA Energy Technology Perspective [1] defined reduction quotas for the major CO_2-emitting sectors, in particular the building, transport, industry and power generation sectors. With regard to the BLUE Map scenario, the power generation sector is the most concerned by these reductions, together with the transport sector. Compared with the baseline scenario, more than a 50% reduction is expected in 2050 by means of plug-in hybrid, electric or fuel-cell vehicles. Passenger road usage represents about 60–70% of all CO_2 emissions in the transport sector. This means that even with a 30% to 50% increase in the fuel economy for Internal Combustion Engines, conventional vehicles alone are unable to achieve the European Union's CO_2 reduction goal for 2050 [2], especially as CO_2 capture is not even considered as a viable solution for the moment. With the soaring price of oil, energy dependence has long become a crucial issue for countless countries worldwide. Global transportation and fossil fuels are inextricably linked. More than 60% of the 87 million barrels of oil is consumed every day by the world's transportation system, while liquid fossil fuels account for more than 96% of the current energy supply to the transport sector. Within the transport sector (Fig. 1), road transport accounts for more than 70% of the total transport energy consumption, which represents 52% for light-duty vehicles (LDVs) [3].

Data from the IEA BLUE Map scenario shows that Electric Vehicles (EVs) and Plug-in Hybrid Electric Vehicles (PHEVs) will provide a 30% reduction in CO_2 emissions by 2050 for LDVs,[1] based on the assumption of 20 million EVs/PHEVs and Fuel Cell Vehicles by 2020.[2] Fig. 2 shows that the market share of electrified vehicles should grow after 2015: the deployment of gasoline vehicles will decrease, thus paving the way for the massive deployment of electric and hydrogen fuel cell vehicles after a 'hybrid vehicle' transition period [4].

From a strict technological viewpoint, it is now obvious that electric mobility has been growing strongly for 5 to 10 years. Available literature already considers fuel-cell and battery vehicles as competing or combined systems, vs. Internal Combustion Engine (ICE) vehicles. This is true from both an experimental and an economic perspective. This complex situation may put many technologies and possible combinations at stake: BEVs, PHEVs and FCEVs are the most frequently mentioned for comparison with ICE vehicles. While electric motors are generally used in FCEVs and BEVs, the architecture (in series or in parallel) of PHEVs determines the choice of motor. Thermal engines (ICEs) are generally employed in HEVs combined with an auxiliary electric motor; they are only refilled with gasoline (see Fig. 3 [5]). Electric power-trains are 2 or 3 times more fuel-efficient than Internal Combustion Engines (ICEs).

Otherwise, pure ICE vehicles remain promising solutions as regards the recent important progress in efficiency. The authors also have their own opinion about various technologies that can influence the choice of assumptions and the conclusions.

This paper raises a number of questions: is a techno-economic approach the only way to analyze future mobility prospects, especially the electric market? How can we define clearly the competitiveness of electric driving? And what kind of impact can driving patterns and consumer behaviors have on this sector?

This paper first analyzes the technical, economical and driving parameters covered in the literature in order to address this complex issue (chap. 2). It then combines these parameters to characterize the competitiveness of electric driving from a mobility angle, thus integrating usage parameters. In addition, the notion of 'range anxiety' is also discussed. Such a combination is very rarely covered in the literature available to date.

2. Background

2.1. Electromobility at a critical step

According to Dijk et al. [6], battery and fuel cell technologies must face the increasing sales and preferences for cheaper ICE cars in emerging markets such as China, as compared with more expensive electric and hybrid vehicles that can be sold in western countries. These authors recently considered BEVs, PHEVs and FCEVs; they assert that electric mobility has crossed a critical threshold and is mainly benefitting from high oil prices and carbon constraints. Nonetheless, they still believe that doubts remain as to whether the fuel-cell technology will be ready for commercial use any time soon. Streimikiene et al. [7] performed a multi-criteria assessment of road transport technologies (BEV, PHEV and ICE with petroleum-based fuels and bio-fuels) which were ranked with respect to five emission indicators and private cost criterion. The analysis showed that the best option according to an 'equal weight' and environmental approach was renewable-based battery-electric vehicles (Re-BEVs), whereas customers would prefer biodiesel from rapeseed.

Thomas [8] viewed the situation from a different angle. He showed that there were two primary options for all-electric vehicles – batteries or fuel cells – and that fuel cells were superior to batteries for any vehicle range greater than 160 km whether in terms of mass, volume, cost, initial greenhouse gas reductions, refueling time, well-to-wheels energy efficiency using natural gas or biomass as the source, and life cycle costs. Furthermore, he believes that a major breakthrough in battery technology is required before a long-range battery EV will be able to satisfy customer needs for conventional passenger cars, particularly with respect to battery recharging times.

When Egbue and Long analyzed the barriers to the widespread adoption of electric vehicles [9], they noticed that sustainability seemed to have less weight compared with the electric vehicle cost and performance, but that the battery range was the biggest concern, followed by the cost.

When Rao and Wang [10] analyzed the development of electric vehicles, they pointed out the vulnerability of the thermal management of batteries. At stressful and abuse conditions, especially at high discharge rates and high operating or ambient temperatures, traditional thermal energy management systems for batteries (e.g. air and liquid) may not be capable meeting the

[1] Light-Duty Vehicles (LDVs) include passenger cars, light trucks, light commercial vehicles and minibuses. The truck category includes medium- and heavy-duty trucks. The bus category includes only full-sized buses. The other category includes two- and three-wheelers.

[2] Technology roadmap: electric and plug-in hybrid electric vehicles; 2011, p. 6–7 [4].

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