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Which energy source for road transport in the future? A comparison of battery, hybrid and fuel cell vehicles

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Abstract

The hydrogen era is foreseen following the European research programme in a time horizon of 2020–2040. But there will be clearly a choice to be made between an electron economy (direct use of the produced electricity) and the so called "hydrogen economy" which leads to the introduction of an intermediate hydrogen production, transport and distribution process before the final use in an electrical process.

This paper considers only passenger car and delivery vans applications. In this field a big time gap is to be filled between the situation today, the occurrence of oil shortage in a quite short future and this time horizon 2020–2040. Today's intermediate solutions are clearly based on hybrid electric vehicles and battery electric vehicles. The performances of these solutions are putting a lot of questions on the necessity of a hydrogen economy for future transportation. The paper discusses performances of hybrid electric vehicles and battery electric vehicles in comparison of the future hydrogen fuel cell based systems which are now in R&D phase and a very beginning of field demonstration.

Keywords: Hydrogen; Road transport; Battery electric vehicles; Hybrid electric vehicles; Fuel cell electric vehicles

1. Introduction

The electric vehicle is an optimum solution for urban mobility as it emits no exhaust fumes. Particularly in cities and in adverse climatic conditions, traffic-generated emissions are degrading air quality up to the point where the physical health of the population is directly threatened. Several cities have already had to apply repeatedly drastic traffic restrictions. The electric vehicle is also ideally suited to be integrated into new traffic management concepts, such as automatic rent-a-car systems and goods distribution centres, or small buses for city-centre services.

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For all these reasons, an increasing number of cities and environmentally concerned companies have introduced electric vehicles in their fleets. Today, there is a clear necessity to generalise the support organised at the European level preparing so the step towards hydrogen electric vehicles.

The oil crisis is clearly in an initial development step and is going to take dramatic dimensions [1–3] calling for an urgent introduction of alternative fuels for road transport with electricity playing a major role. However the electricity, storage remains a key point. The development of alternative battery systems shows the possibility of making a real technical and economic breakthrough in a short or medium term consistent with an important market development. New battery types such as high-temperature batteries, Nickel-metal hydride batteries, and lithium-based batteries are already on the market or will be available in the coming years. Due to their high energy density (70 W h/kg for NiMH and 125 W h/kg for Li compared to 40 W h/kg for Pb and 60 for NiCd [4]), they will offer unprecedented vehicle ranges, up to 250 km and even much more through the introduction of range extenders. A powerful public national and European support is still necessary as well as an effective marketing approach.

The long-range or multi-mission electrically driven vehicle will become a reality through the development of hybrid drive trains. Hybrid vehicles combine electric and other drive systems, such as internal combustion engines, gas turbines and fuel cells. The main advantage of this combination is the permanent interaction between the highly efficient electric system and the thermal engine or fuel cell. Here too, the power batteries or other power boosters such as super capacitors play a key role. A number of reliable vehicles are coming on the market today with a large spectrum of hybridisation ratios (from start and stop systems to full hybrid power train).

Due to the inbuilt dual function hybrid vehicles have a longer range than battery electric vehicles. They can offer the option of running on electricity alone in urban environments so being locally zero emission at this time. Some of these vehicles can be plugged-in using conventional or renewable sources of energy to produce electricity in an effective way.

The hybrid technology is now particularly favoured for heavy-duty vehicles such as city-buses and leads to 20–30% reduction in both energy consumption and associated emissions.

Several studies have investigated the well-to-wheel energy consumption of vehicles using alternative fuels or drive trains [5–8]. Several pathways to produce hydrogen and other fuels and to use it in several internal combustion engines, hybrid drive trains or fuel cell vehicles are compared in these studies. However a comparison with battery electric vehicles is mostly omitted in these studies.

The objective of this paper is comparing the battery and hybrid electric vehicles with conventional vehicles and fuel cell electric vehicles on the basis of energy consumption. The duality between battery electric vehicle and fuel cell electric vehicle will be extensively demonstrated in the following sections.

2. Facts related with the mobility of people and goods

Let us highlight some facts about the mobility of people and goods.

2.1. Employment—economy

The European transport industry is an important economy sector as stated by the following data (for the 15 EU member states): 14 million workers or employees (i.e. 10% of the active population) where less than 6 million in the transport services, 2 million in the equipment sector and 6 million in transport connected activities. Fourteen percent (14%) of families' revenue are devoted to transport. The modal distribution of the people mobility expressed in passenger kilometers (p.km) sounds as follows: 79% by car, 8% by bus, 7% by air, 6% by rail and less than 1% by tram or underground. The modal distribution of goods transport formulated in ton kilometers (ton.km) show a different picture: 43% by road, 41% by sea, 9% by rail, 4% by land waterways and 3% by pipelines.

The total added value (EU15) of the automotive industry is around 290 BEuro. However there are also important external effects due to our mobility like pollution, congestion and safety. The total external cost is estimated to have the same order of magnitude as this added value, namely 225 BEuro.