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Short Communication

Why Hydrogen Energy Storage in Vehicles will Succeed Batteries

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Abstract

In 2024, 17 million Battery-Electric Vehicles (BEVs) were manufactured globally, contrasting with about 15,000 hydrogen-electric vehicles (HEVs). This article considers the reasons for this result, suggesting that an optimum design of a Hydrogen plus Fuel Cell plus Battery Electric Vehicle (HFCBEV) drive train can beat the pure battery on fast refueling, mileage range, and cost. The difficulty is hydrogen infrastructure because hydrogen is not generally available to the public whereas electricity is accessible in almost every home. However, electric infrastructure is not available to charge bigger batteries that are now being installed in BEVs up to 250kWh energy storage. The conclusion is that small electric cars with batteries below 100kWh will be satisfactory but larger designs will shift to hydrogen electric vehicles as new refueling infrastructure is built by government leverage.

Introduction

By 2024, 194 states plus the EU had ratified the Paris Climate Change Agreement, representing over 98% of global greenhouse gas emissions, leading to electric vehicles replacing fossil fuel combustion engine designs across the globe [1]. The most successful product has been the lithium battery car [2], manufactured in large numbers nearly 17 million per year with China taking the lead as BYD overtook Tesla, shown in Figure 1. Neither of these two top companies has built hydrogen electric cars. This seems surprising at first sight because Hydrogen energy storage displays significant advantages compared to the Lithium battery. In Germany, Daimler, BMW, and Volkswagen have been testing hydrogen cars since 2000 [3].

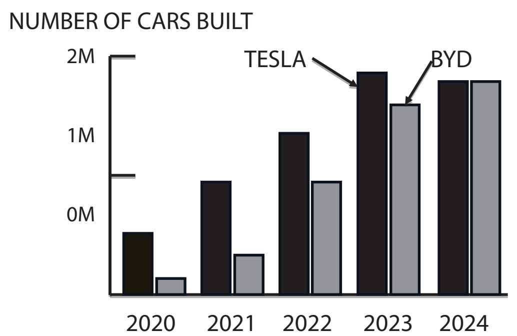

Figure 1: BYD overtaking TESLA in 2024 [4].

Table 1 shows that hydrogen gas molecules contain more energy per kg than lithium metal while costing much less, but both materials have containment issues giving very much reduced contained energy with far higher contained cost [5]. The key invention from Toyota was the lightweight polymer Type 4 cylinder that improved gas storage performance at 700 bar pressure.

Since 2016, it has been possible to compare the characteristics of two competing drive-trains, the pure battery of the Tesla X and the hybrid Hydrogen Fuel Cell Battery concept of the Toyota Mirai. The 2021 Mirai shows several advantages over the Tesla X which is approximately the same weight nearly 2 tons. It stores 200kWh of energy in its 6kg hydrogen tanks, double the 100kWh in the Tesla X. Therefore, the Mirai has a range of 400 miles that beats the 300 miles of the Tesla X (rounded numbers depend on driving conditions). The main advantage is that the hydrogen can be refueled in 5 minutes, far faster than electric charging a Tesla X on a 4kW home circuit that takes a day. In Britain, the additional benefit of the Mirai is that it costs £50K whereas the Tesla X is priced at £92k.

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The key problem is hydrogen infrastructure, which is relatively low cost around £1M per station, but has never before been available to citizens, whereas electric power is in every home. Only China has managed to add one hydrogen station for every 100 new hydrogen vehicles. Other countries have failed to match supply and demand, causing market chaos. Of course, hydrogen must be green to get costs below fossil fuels, as mandated in the EU and UK. But not known in China.

The problem with larger battery vehicles is that the battery must be bigger, heavier, and more expensive, exemplified by the 2022 electric Hummer that has a 237kWh battery weighing 1.3 tons, itself heavier than the average UK car [6]. Home charging infrastructure in the UK cannot handle such a large battery which could take 2 days to refuel. Consequently, hydrogen energy storage becomes rational for vehicles that require more than 100kWh batteries. Although the car industry has accepted that 1000 battery cars (BEVs) are currently made for each Hydrogen Electric Vehicle (HEV) to lead the market, the number of hydrogen vehicles is still increasing exponentially. When plotted on a log scale, the HEV is clearly behind the BEV by 16 years but will catch up as the Chinese BEV curve levels out at an estimated 100 million [7]. The date is predicted to be around 2040 on the evidence of the extrapolated results in Figure 2.

Many market analysis companies have predicted a rise in HEV popularity to 2032-2035 with approximate annual increases ranging from 20 to 50%, though the 2023-2024 results were not positive [8-10]. The numbers are risky because they depend on Government definition, which has been dominant in China but low in the UK and USA.

Conclusion

The conclusion is that BEVs will dominate the market for batteries with less than 100kWh energy storage that can be charged with existing electric Grid infrastructure, but hydrogen energy storage will become more appealing as widespread hydrogen infrastructure is installed. China is ahead on this key point, whereas capitalist countries have failed to match the supply of HEVs with the addition of green hydrogen refueling stations, a simple error that is easy to fix by government edict.

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Table 1: Comparison of Lithium and Hydrogen molecules for energy and cost.

	LITHIUM metal	HYDROGEN gas
Molecule energy	12 kWh/kg	40 kWh/kg
Molecule cost	10 $/kg	0.8 $/kg
Contained energy	0.2 kWh/kg	1.7 kWh/kg
Contained cost	100$/kWh	14 $/kWh

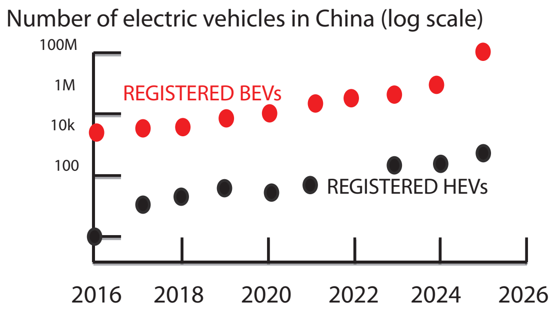

Figure 2: Comparing the rise of battery vehicles with hydrogen vehicle growth in China.

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