An Analysis of the Alternatives to the Internal Combustion Engine

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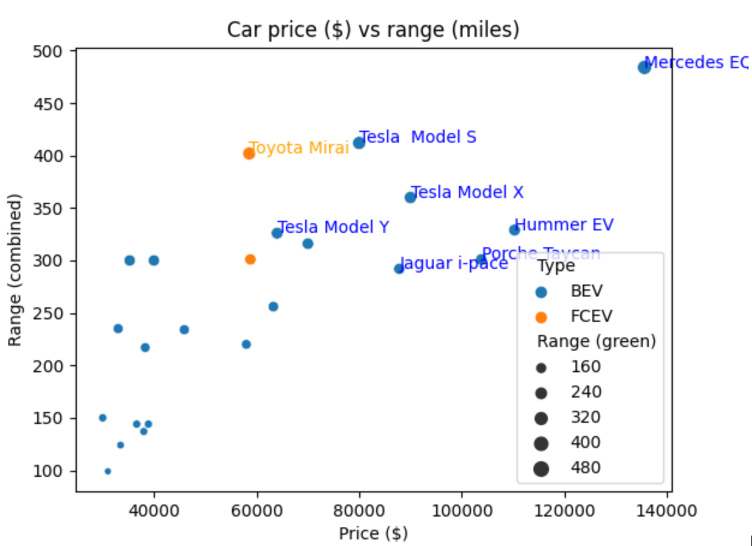
As the world moves away from Internal Combustion Engines (ICEs) and non-renewable energy, we are quickly needing an alternative power source for cars. The two biggest contenders are Hydrogen cars (Fuel Cell Electric Vehicles, FCEVs) and Battery Electric Vehicles (BEVs). FCEVs are powered by joining hydrogen and oxygen to make water, using the electricity emitted to power the car, while BEVs take mains electricity to charge the battery inside the car and power electric motors. The primary vehicles analysed in this paper are the Toyota Mirai (FCEV) and the Tesla Model Y (BEV). Right now, the world is heading towards BEV, but is that the right course of action? Should we be looking to Hydrogen for answers?

Hydrogen and battery electric cars both have their pros and cons, and this essay will discuss five main factors: cost of ownership, efficiency, infrastructure, ethics, and limitations.

Cost of ownership

The range of the Toyota Mirai is 400 miles and with a cost to fuel around £10-15 per kilogram, the car would cost £44.20 to refuel its 37-litre tank, resulting in an approximate cost of 16.3p/mile. The refuel time for the Toyota Mirai is around 5 minutes. On the other hand, the Tesla Model Y has a range of 315 miles, using public high-speed chargers, results in approximate cost of 6.65p/mile [12]; charging times vary from 40 minutes with a Tesla Supercharger to 12 hours at 7.4kw.



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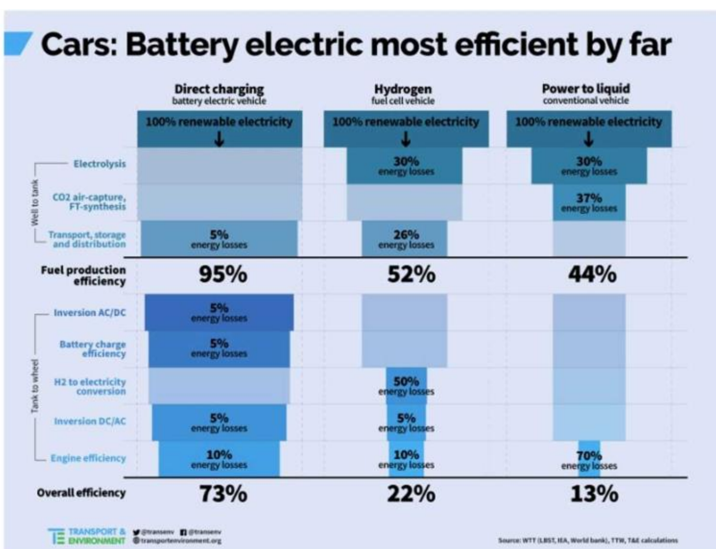
The currently available FCEVs are not luxury cars and hence when compared to similar BEVs (e.g. Hyundai Kona) have a significant premium, although the Mirai has 30% higher range. (See graph above.)

The cost of the car does not exhibit a high correlation to the range as there are cars with ranges around 300 miles that are less than $40,000. There are also cars that cost in excess of $40,000 but have a range less than 150 miles. Luxury electric cars tend to have a premium as shown by the Porsche Taycan that costs over $100,000 and yet only has an approximate range of 300 miles.

Efficiency

Hydrogen can be produced in many ways, but as the world needs renewable, green energy for transport, the only way to produce it for the long term is through electrolysis. While neither the most efficient nor the cheapest method, it is the most environmentally friendly. Natural gas reforming is another way, but it releases toxic gasses into the atmosphere. There are several processes between extraction and usage of hydrogen in the vehicle, each of which has some inefficiency, resulting in an overall loss of 78%. This compares unfavourably to electric vehicles, which only lose 27% from generation to charging the car [1].



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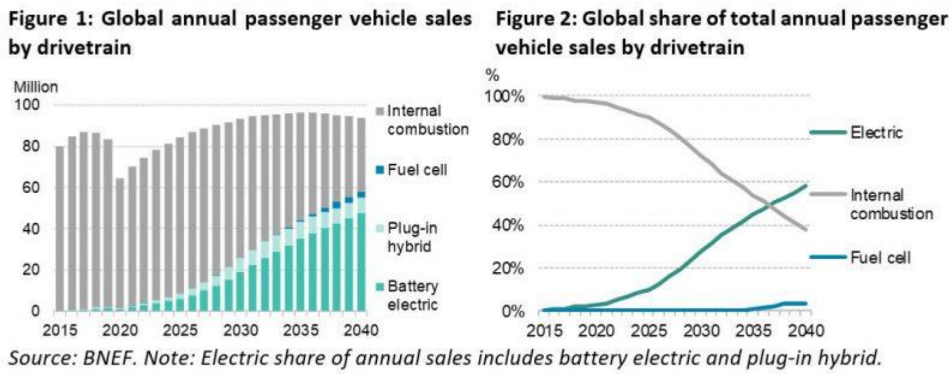
Infrastructure

Currently, there are 30,000 BEV stations in the world, but only 432 FCEV stations [7]. FCEV adoption has not taken off yet and is not predicted to in the next 20 years, The primary reason for this is because of the heavy expenses including fuelling, pump construction. There is a circular problem for FCEVs, the expense of construction of infrastructure and fuelling cannot be justified due to the lack of consumer demand, but the lack of consumer demand is partly caused by the lack of infrastructure. The only solutions for this are government intervention or industry creating significant investment similar to Tesla creating the supercharger network in the US.



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The total Toyota Mirai sales for 2020 was around 499 in the US while there were 81,000 Tesla Model Ys sold in the US (see graphs above). There are over 350 different models of electric cars compared with the 6 hydrogen models on the road today.

FCEVs and BEVs both need to recharge. The average refuel time for a hydrogen car is 5 minutes, but then the refuelling tank needs 15 minutes to repressurise [2], so if the pump was run 24 hours a day for an entire year, that pump would serve 25,632 customers. One pump costs £1.1 million and if it had a ten-year service lifetime and was running 24 hours a day, every day, to make profit after the installation costs, the station would have to charge £4.30 per customer. This is unrealistic as a pump would not run 24 hours a day and might need servicing. The cost of Hydrogen and employee wages would also bump up the customer cost.

The charge time for the for the Tesla Model Y with a Tesla supercharger in 45 minutes, but it would take a regular wall socket 12 hours to charge a Tesla Model Y from empty to full. More BEV charge points are being installed and with unit prices ranging from £1,500. This makes them a lot cheaper than hydrogen refuel points at £1.1 million. There are also plans to make BEV stations that swap out batteries, [6] but this is potentially expensive and impractical as more BEVs will be on the road and the batteries will not get a chance to recharge between customers.

Ethics

One of the problems with the production of electric cars is the use of cobalt in the battery. Cobalt is used to boost the energy density and life of the battery. It also keeps the structural stability of the battery while the lithium-ions get extracted from the cathode. For example, Tesla uses around 3kg of cobalt in each battery, but some other manufacturers use up to 14kg. [8] Cobalt is mined mainly in the Democratic Republic of the Congo (DRC). This is a problem because the DRC has an endemic issue with corruption. Cobalt is traditionally mined by unregulated artisanal miners;

conditions are arduous and are incredibly dangerous because of collapsing, with over 100 deaths every year.

Increasing demand is attracting large scale mining companies such as Glencore. Tesla, not owning any mines, has a partnership with Glencore. As the country is corrupt, Dan Gertler (a businessperson that owns the gold and cobalt mines in the DRC) managed to illegally gain the rights to the mines, so Glencore must pay Gertler to lease mines on that land. Glencore is threatening to evict all the artisanal miners who currently mine on their land [10].

Lithium and cobalt mining releases toxic by-products such as sulphur into the air and pollutes ground water. However, there are newer battery technologies that have the potential to be less toxic to the environment [15] [11].

Limitation

Both FCEVs and BEVs have limitations. Hydrogen is a highly flammable gas, with extremely small atoms meaning it leaks from fuel tanks. BEVs have a low energy density which means cars with a large range are heavy and trucks with large ranges would be extremely heavy. In addition, lithium is a relatively scarce resource used for batteries in most consumer devices including phones, computers and cars. This significant and increasing demand means that there will be significant supply challenges to upscale production. There is ongoing research regarding recycling lithium batteries that may relieve this problem.

Due to the huge trucks used in mining using up to 134 litres of diesel an hour, Anglo American is making a hybrid truck where half the power comes from hydrogen and half comes from the battery. When the truck brakes or goes down a hill, the battery would recharge. The hydrogen would mix with oxygen to make water, the water catalysed with platinum would generate the electricity needed to power the truck. This would make mining more eco-friendly as right now 36% of the total C02 emissions comes from mining [16].

Conclusion

BEVs are more efficient, cheaper, and less expensive to charge, but there are ethical challenges, they have a smaller range and they take longer to charge than hydrogen. In the next ten years we are likely to see: improved batteries, shorter charge times and longer ranges for BEVs. Recently, scientists have discovered a way to extend battery life and stop the batteries degrading over time. Hence BEVs are the natural successor to the ICE.

Hydrogen has a higher energy density and, therefore, is more suitable for larger vehicles, long distance lorries [4], mining vehicles [16] and planes [17]. All of the above need fuel delivered in bulk to a few specific points, as opposed to a large-scale consumer delivery network, and, hence, is more efficient.

Sources

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