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The Development of Hydrogen Technologies in Motorsport

Academic Skills – ACHA4005

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1 Introduction

This report will focus on the emergence of hydrogen technology in motorsport, the importance of this technology in terms of sustainability, and how this technology can be — and already has been — transferred to road-going vehicles. The primary purpose of this report is to highlight the sustainability benefits of hydrogen and compare the efficiency of hydrogen fuel cell vehicles to both hydrogen ICE vehicles and standard ICE vehicles, in addition to exploring why most manufacturers have abandoned hydrogen research.

2 Background

Due to the ongoing effects of climate change, there has been a swift need and demand for sustainable, environmentally friendly fuels to substitute those that are derived from crude oil. In the automotive and motorsport industries, electric vehicles have been widely adopted. This is due to the already existing infrastructure which can support this. However, there is minimal infrastructure which can support the mass-production of hydrogen vehicles. The main reason for this is the difficulty of storing and then supplying hydrogen to cars quickly at fueling stations, which makes hydrogen very expensive when compared to electric charging, which can be done relatively easily at charging points that are connected to the grid. Where motorsport comes into this is that car manufacturers, namely Toyota, are experimenting with new ways of storing hydrogen, and then fueling cars mid-race to reduce fueling time and to understand better the methods of hydrogen storage.

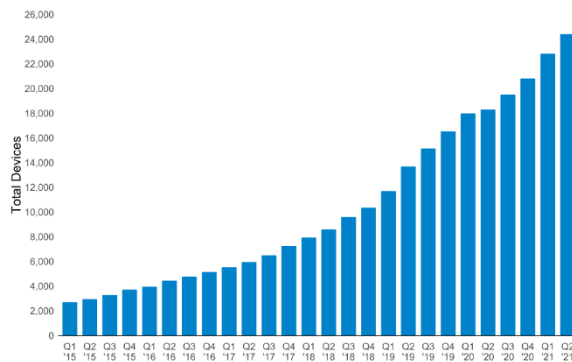


Figure 1 – The growth in UK public charging devices (Department for Transport, 2021)



Figure 2 – The number of UK hydrogen car refueling stations (UK H2Mobility, 2023)

Figures 1 and 2 show the difference in existing infrastructure capable of supporting electric and hydrogen vehicles. These highlight the consensus that, currently, electric is more viable than hydrogen as a sustainable alternative to gasoline vehicles.

3 Discussion

There are two main storage methods for hydrogen-fueled vehicles: liquid hydrogen storage, which is used for hydrogen internal combustion engines (HICEVs) and gaseous hydrogen storage, which is used for fuel cells. There are advantages and disadvantages to both types of storage systems. The main advantages of the liquid hydrogen system when compared to gaseous is an increased driving range and a non-pressured tank, allowing for multiple cars to be fueled in succession as shown in Table 1.

Advantages of Liquid Hydrogen	Challenges with Liquid Hydrogen
Increased energy density and cruising range	Must be kept at temperatures below -253°C
Smaller hydrogen stations (can be filled in the pit)	Preventing hydrogen from evaporating due to heat in the tank
Doesn't need to be pressurised, allowing for multiple vehicles to be refilled in succession	Fuel pumps tech. that can function at -253°C

Table 1 – Advantages and disadvantages of liquid hydrogen storage compared to gaseous storage (Toyota, 2023)

This is very important in motorsport, as an increased driving range means less time spent in the pits refueling, saving teams valuable laps in a race. The increased energy density of liquid hydrogen increases the efficiency of vehicles, which is what significantly increases the driving range. The ability to also refuel multiple cars in quick succession can also be very advantageous during a race, as there can be safety cars or full course yellows, which teams can use to their advantage by losing less time in the pits. In contrast to this, with the gaseous system of storage, the cars must be taken behind the pits due to the sheer size of the refueling system, but with the liquid system of storage cars are able to be refueled in the pits and in quick succession, which could be the difference between winning and losing a race.

Despite these two great advantages of liquid hydrogen storage, there are two main drawbacks to this. The weight of the required hydrogen in a 1 cubic meter tank is 71kg for liquid hydrogen, and 40kg for gaseous hydrogen stored at 700 bars. In addition to this increase in hydrogen weight, the additional equipment needed to be able to vaporize and pressurize liquid hydrogen for combustion adds an extra 250kg to the car's weight. In the case of the H2 GR Corolla at Fuji Speedway, this caused an decrease in lap time of around 4 seconds (Engineering Explained, 2023).

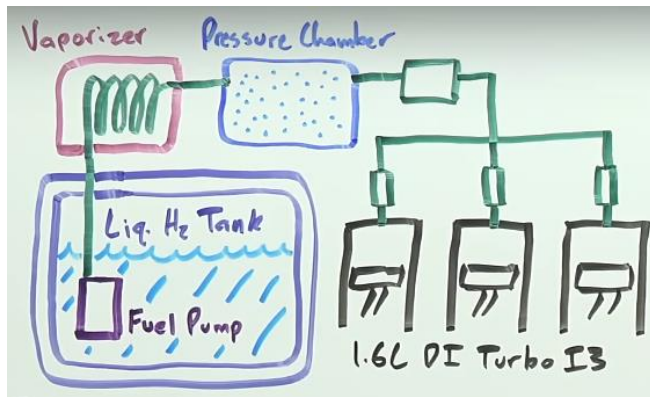


Figure 3 – A drawing showing the liquid hydrogen system used in the H2 GR Corolla (Engineering Explained, 2023)

The requirement for the hydrogen to be stored at such low temperatures also creates substantial issues with the fuel pump. With current technology, the fuel pumps used in liquid hydrogen systems are not able to last much longer than 8 hours when used in a racing environment. This is due to the extreme temperature causing much faster wear on a fuel pump. When put to the test in Toyota's 2023 24h Fuji attempt with the H2 Corolla, the fuel pump was changed twice, taking around 3.5 hours each time, losing the team 7 hours of total running time.

The sheer weight and size of these liquid hydrogen systems is the main barrier to entry when concerned with road cars. The increased weight of liquid hydrogen vehicles causes increased usage of the fuel, which in-turn decreases the efficiency. However, with the increased energy density of liquid hydrogen, less mass of the fuel is used, so this small decrease in energy is offset. The tank which is used to store the hydrogen is very large too, with rear seats often being removed to accommodate the large tank. This is of course a major problem when dealing with road-going vehicles, as many of the potential customer base of sustainable, zero-emission hydrogen cars are likely to be families who are aware of their carbon footprint and want to reduce their own.

This is why hydrogen fuel cells/ hydrogen electrics are also being researched and developed. Öner and Yurtcan (2023) suggest that it is more effective when storing large amounts of hydrogen at moderate temperature and pressure, which is much like current fuel cell electric vehicles (FCEVs) that are currently on the road. FCEVs use hydrogen tanks, pressurized at 700 bars, where hydrogen is distributed to the anode of the fuel cell system. On the cathode side, negatively charged oxygen from the air is taken and is then fused with the positively charged hydrogen and creates water. This also generates electricity, which flows to the electric motor, which is the same as those used in battery electric vehicles (BEVs), which powers the car.

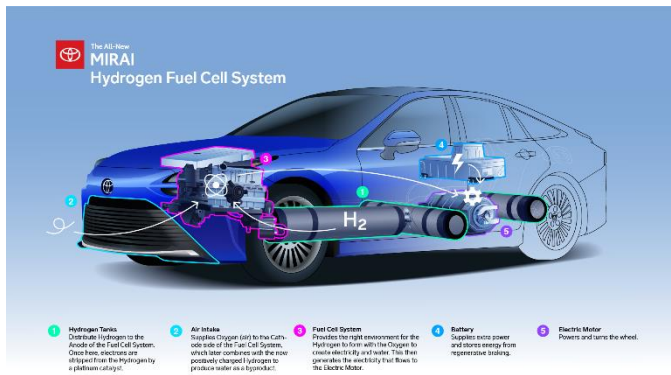


Figure 4 – How the hydrogen fuel cell system works (Toyota, 2021)

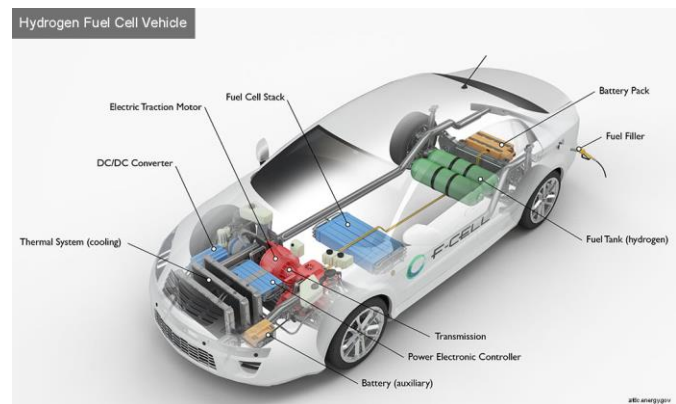


Figure 5 – The essential components of a FCEV (Department of Energy, 2023)

Synthetic fuels are also a major development point in the increasing importance of sustainability around the world. These fuels are able to be used in existing ICE vehicles, making them much more readily useable than both FCEVs and liquid hydrogen-powered vehicles. In addition to this, it is much cheaper to store synthetic fuels too, as they can essentially replace those derived from crude oil, where the technology and infrastructure is widely available and ready to support this. However, with synthetic fuels, the processing facilities which extract carbon from the atmosphere are still quite expensive, and with the possibility of the widespread use of these fuels, availability will increase, causing falling prices (Bosch, 2023). While synthetic fuels still do emit carbon dioxide (CO₂) at similar levels to traditional oil-based fuels, the extraction of CO₂ to produce synthetic fuels offsets the emissions produced by vehicles.

Within motorsport, sustainable fuels are a large topic of discussion for the future. Whilst at the moment, no major racing series runs on completely synthetic fuel, OEMs are researching how quickly and efficiently synthetic fuels can be introduced into worldwide motorsports to decrease carbon emissions. Toyota recently debuted a synthetic fuel-powered GR86 in the Super Taikyu endurance series in Japan, the same series in which they raced the hydrogen-powered GR Corolla. The Carbon-Neutral Fuelled (CNF) car performed to a much higher standard, completing 640 laps compared to 358 laps with the hydrogen Corolla. This indicates that synthetic fuels are a much more viable alternative to hydrogen with today's infrastructure and technology, due to the better efficiency and the already existing infrastructure which supports the use of synthetic fuels.

4 Conclusion

There is one simple conclusion to draw from this report: Whilst the promise of zero-emissions and a clean future if hydrogen cars were to be mass-produced, there are other sustainable methods which are widely available now and are much cheaper to develop. The technology involved in hydrogen research could become very important, however this would not be for a long while. Where synthetic fuels can replace oil-based fuels, hydrogen researchers have to create an entirely new system to support hydrogen vehicles. There are some hydrogen fueling stations already open, however there is simply not enough, and fuel is still too expensive to be able to support a mass-production of hydrogen vehicles. However, manufacturers such as Toyota are showing that a hydrogen future is possible, with its hydrogen race car programs with the GR Corolla, and transferring the same technology into road-going vehicles such as the Mirai. Within motorsport itself, it seems that there will be little hydrogen adoption in the future, as synthetic fuels and EVs are already showing themselves to be much better for hydrogen, in terms of cost benefits and availability.

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