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Use of Energy Carriers; Legislation & Practicality

Approach

Automotive Materials & Sustainability (ACHA6012)

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1 Introduction

In recent years, there has been growing concerns about the impact of motorsports on the environment. As the world continues to shift towards sustainability, the need for sustainable solutions in the racing industry is increasingly important. This report aims to prove the advantages and disadvantages of different energy carriers proposing what would be the recommended decision for Formula Drift, discussing what they should implement to improve their carbon footprint. A feasibility study has been developed summarising how the energy carriers compare with each other, the study's criteria covers cost, emissions, infrastructure, safety, efficiency, and practicality. Not only will this report cover the racing series, but it will also suggest how Formula drift can encourage the circuits they visit to improve their carbon footprint, with information about different ways to generate electricity at the circuits but also ways of offsetting their carbon footprint by investing in organisations to support carbon offsetting. This report will consider how the infrastructure will be affected and what needs to change but will also cover macroenvironment point of view with key point towards the spectators and how they view the sport.

2 Legislation

When proposing ideas to improve the sustainability within Formula drift detailed research of the current regulations need to be done. Looking at the section with regards to the fuel carriers it is made clear that only internal engine combustion engines (ICE) are permitted and may only run on petrol, diesel, or ethanol. The regulations also state that electric/ hybrid engines are eligible for competition with prior written approval from the competition director (Formula Drift, 2023). When analysing Formula drifts efforts in improving the sustainability there is no evidence to support future improvements. Within the FIA environmental report of 2022 it discusses the aims and objectives with regards to its sustainability by the year 2025, there is key ambition that the world championships need to improve their carbon footprint with two key quotes as follows “ By the end of 2021, define specific plans for the application of electrification and new green technology in FIA championships” and “ By the end of 2021, all world championships to develop action plans linked to waste, biodiversity, transport and energy management” (Sulayem & Calderon, 2022). The FIA have also announced that sustainable fuels will be implemented in the world endurance championship, world rally championship and karting by 2023 (FIA, 2022). Taking a similar approach to the FIA would be a recommended course of action to improve the carbon footprint of the series significantly. Therefore, Formula consider setting a goal of being carbon neutral within the next few years detailing methods on how they are going to achieve this.

3 Energy Carriers

Currently within motorsport most racing series require the use of petrol/ ethanol with the obvious exceptions of the electric series. However, there are no championships utilizing alternative energy carriers such as hydrogen combustion, hydrogen fuel cell or synthetic fuels. This section of the report outlines the operation and effectiveness of alternative energy carriers.

3.1 Hydrogen Fuel Cells

Hydrogen fuel cells work like batteries however they do not run down or need recharging, they produce electricity and heat as and when a fuel is supplied (Office of Energy Efficiency & Renewable Energy, 2014). Within a hydrogen fuel cell, the chemical energy is stored in hydrogen gas and directly converted into electrical energy through an electro chemical process. Hydrogen is fed into the anode side of the fuel cell reacting with a catalyst (usually platinum) breaking down the hydrogen atoms into protons and electrons. Oxygen is fed into the cathode. The electrons go through an external circuit creating a flow of electricity which can be used to power electric drive motors. The protons travel through an electrolyte to the cathode, where they reunite with oxygen and electrons to produce water and heat (Linquip Team, 2022). This process can be surmised by figure 1 below.

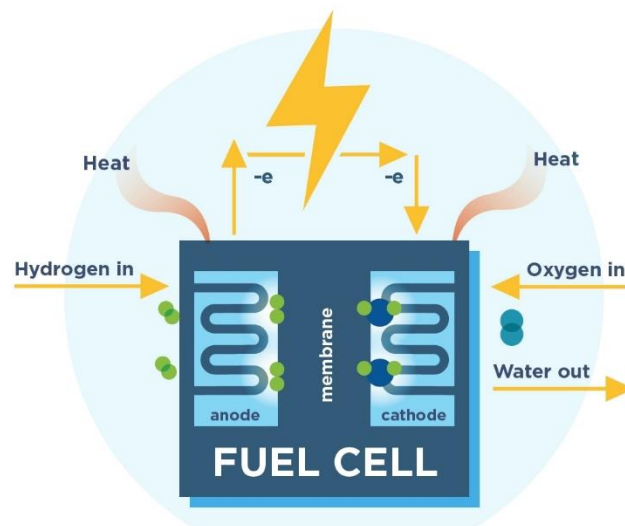


Figure 1 - Fuel Cell Process (Linquip Team, 2022)

Fuel cells exhibit a remarkable advantage over ICE in terms of efficiency and emissions. When converting the chemical energy into electrical energy efficiency levels of up to 60% are achieved (Linquip Team, 2022) because of the absence of combustion and moving parts. Whereas an ICE will extract 20 - 30% of the available energy from petrol with the rest being dissipated due to heat and friction (Corby, 2022). Because the fuel cells only emit oxygen and water they are therefore classed

as zero-emission vehicles. However, the type of hydrogen that is used is a contributing factor, as to whether emissions are produced within the production of the hydrogen. Based on the source of production, hydrogen can be classified into 9 different categories however the main types are green, blue, and grey hydrogen (Kemical Info, 2022). Green hydrogen produces no harmful greenhouse gas emissions. Produced by electrolysis of water where no CO₂ is produced. The electricity for the electrolysis is supplied by a fully renewable source such as solar or wind energy etc. Due to the production being so costly green hydrogen only makes up a small portion of all hydrogen however this cost is expected to decrease within the near future (Kemical Info, 2022). Blue hydrogen is described as a 'low-carbon hydrogen'. Blue hydrogen is produced from non-renewable energy sources such as natural gas. This natural gas is split into hydrogen and carbon dioxide through steam methane reforming. The downside of this method is the obvious factor of producing carbon dioxide as a by-product. Carbon capture and storage is essential to trap and store this carbon (Pratt, 2022). Finally, grey hydrogen, the difference between the blue and grey hydrogen is whether the waste gases are stored or released into the atmosphere consequently grey hydrogen is less environmentally friendly. It is crucial to make the right decision in choosing either green or blue hydrogen in a plan to becoming net zero. Finally, the cost of running a hydrogen fuel cell, current prices for hydrogen are around £10 - £15 per kilo. Taking the fuel consumption from the Hyundai Nexo, a hydrogen fuel cell vehicle which consumes 0.95kg per 100km will cost around £11.40 to cover 100km while an equivalent petrol will cost around £6.72 to cover the same distance. (RAC, 2020).

3.2 Hydrogen Combustion

Hydrogen combustion engines generate power through combustion of hydrogen using a fuel supply and modified gasoline engine injection system (Toyota, 2021). Hydrogen engines emit zero CO₂ when in use other than the minutes amount of engine oil when driving likewise with a petrol engine whilst having excellent environmental performance. The combustion occurs at a faster rate than in gasoline engines resulting in good response characteristics as stated from (Toyota, 2021). Hydrogen engines also have the potential to relay the fun of driving including through sounds and vibrations which proves beneficial for a macro environmental aspect with regards to a social effect, Bernie Ecclestone once said that he was 'horrified' by the noise reduction when the V8's within F1 were replaced by v6 turbo-engines. Ron Walker chief of the Australian grand prix complained that fans at the grandstand at Melbourne could barely hear the cars coming down the straight he quoted "when you take the excitement away, you take the tickets away" (Esler, 2014) therefore using an energy carrier which remains to have sound properties will have a viewer benefit as well as an

environmental aspect. When analysing the cost of running hydrogen combustion due to their being no evidence on efficiency levels the running costs cannot be calculated.

3.3 Synthetic Fuels

As of 29th March 2023, a deal between Germany and European legislators has passed that allows the exemption of e-fuels from the ban on internal combustion engine cars in 2023. Allowing this legislation to pass will increase the likelihood that the infrastructure and affordable access to e-fuels in the future will broaden (Goodwood, 2023). E-fuel production is based off the extraction of hydrogen via electrolysis of water being broken down into hydrogen and oxygen. The high amounts electricity required for electrolysis is generated from renewable energy sources like wind and solar energy. The hydrogen is then combined with CO₂ extracted from the air and converted into a liquid energy carrier via a process called Fischer-Tropsch synthesis (E-fuel Alliance, n.d.). This process is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen known as syngas into liquid hydrocarbons (Gharibi, 2012). This is then processed in refineries and can completely replace conventional fuels with the only by product being CO₂ nevertheless zero petroleum state that when using their fuel “The same amount that is emitted, is used to create the next batch of fuel, creating a carbon neutral energy cycle” (Zero Petroleum, 2021). Although this method doesn’t reduce the current and past emissions it will have a contributing factor into reducing the rate at which the emissions are increasing. The downside of synthetic fuels is the additional costs Porsche’s synthetic fuel currently costs £1.62 per litre (Stevens, 2022) which as of 31/03/2023 is the same price as Shell’s v-power (Local Prices, 2023).

3.4 Electric Powertrain

The final energy carrier that will be analysed within this report is the use of a fully electric powertrain, an electric powertrain is broken into 4 key components; the motor, which generates the power for moving and the regenerative braking power during deceleration. The inverter, utilizing the motor it converts the direct current electricity from the vehicle's batteries to alternate current. When driving, the inverter can also aid in energy recover as it can reconvert the alternating current back into direct current during deceleration allowing it to be restored within the battery. Reduction drive, this modulates the rotations of the motor transmitting the power to the wheels. Finally, the power delivery module (PDM) this plays a crucial role in the efficient and safe operation of an electric powertrain by managing the power flow from the battery to the motor. Electric powertrains emit zero emissions when being driven however the production emissions for electric cars are

enormous, a study from the union of concerned scientist found that manufacturing a midsize electric vehicle would produce 15% more emissions than building a similar gas-powered vehicle. For a larger vehicle this could increase to 68% (Matousek, 2019). As can be seen in figure 2 due to the production emissions the initial point for electric vehicles is significantly higher than that of the ICE with the breakeven point of a wind powered electric car being at 45,000km. However, with track lengths varying between 0.86km and 4.32miles (Formula Drift, 2023) it is unlikely that the electric powertrain will ever reach 45,000km. Consequently, the benefits of the zero exhaust gas emissions are outweighed by the production emissions.

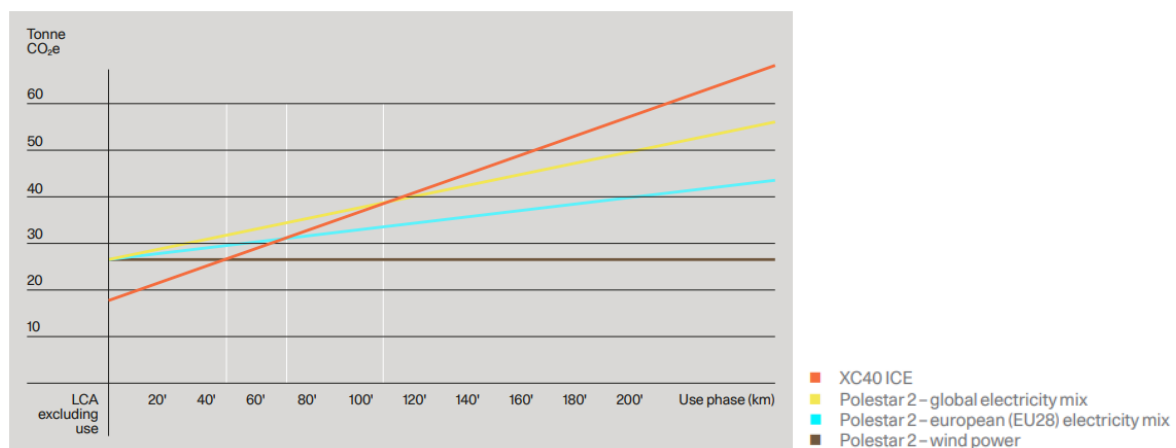


Figure 2 - Polestar 2 life cycle report (Polestar, 2020)

Furthermore, the RAC tested a VW ID.3 compared to a VW golf and over 12,000 miles the Golf cost £1,575.28 (At 147.3p per litre) whereas the ID.3 cost £428.30 (At 16p/Kwh) which is a significant saving (RAC, 2022). This could be further improved if the electricity was generated by the circuits.

4 Energy Recovery Systems

Within the sport there is an energy loss in the form of kinetic and/or heat energy. To make the sport more energy efficient the energy that is being lost from the vehicle can be restored. Especially when it comes to braking, the drivers use the handbrake and left foot brake heavily to control the car when drifting, these are crucial areas where energy can be restored. Regenerative braking converts kinetic energy generated during braking into electrical energy and can be stored in a battery or capacitor, this stored energy can then be used to power the vehicle or assist the engine during acceleration. As a result, not only will it improve the performance and efficiency of the engine but also reduce the emissions due to the frequent accelerations and decelerations (Islameka, 2023). Another technique to restore the energy loss through the kinetic energy generated within the flywheel this will be highly beneficial within the sport because the cars achieve high wheel speeds when in drift. Issue with using a storage for power is deciding when it can be used. Within formula 1 drivers are allowed to release 400kJ of energy per lap, however with drifting there is only 2 laps per round. Therefore, rather than storing the energy the energy could be inputted straight back into the vehicle using electric motors with the introduction of a hybrid system.

5 Impacts on Circuit Infrastructure

Introducing a new energy carrier in race circuit infrastructure would require significant changes to support the new energy source. A network of electric charging stations or hydrogen fuelling stations would be required to support electric or hydrogen powered vehicles. This added demand could occur in issues with local power grids potentially needing upgrades to transformers and cables to enable sufficient power supply. One way to resolve this is for the circuits to generate their own electricity, using solar panels and/or wind turbines. Energy storage systems such as batteries and hydrogen storage tanks can be utilized to store excess energy generated during non-peak times. This will reduce the electricity demand at local power grids but also reduce emissions at the track due to the electricity being generated by a renewable energy source. As seen in figure 3 using wind or solar energy has a significant impact in the reduction of CO₂ emissions when compared to coal.

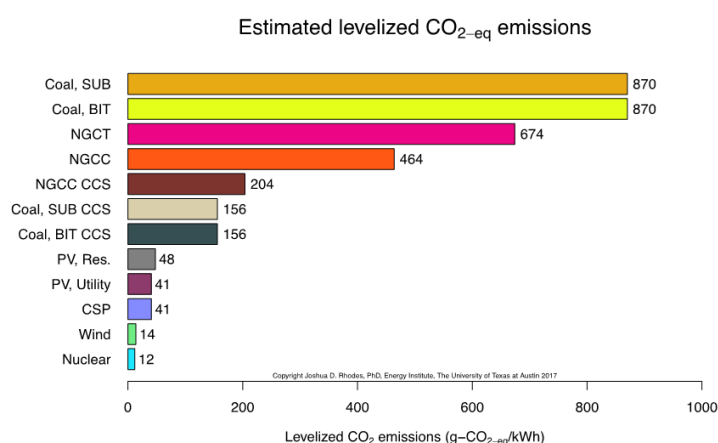


Figure 3 - Estimated CO₂ emissions for different energy sources (The University of Austin Texas , 2017)

Furthermore, new safety protocols would need to be developed to address the potential hazards associated with electric and hydrogen vehicles. Similar approaches could be taken from Formula E. They have introduced a 'red car' safety procedure, where a light on the car illuminates red if the electrical components on the car have been damaged at any point. This notifies all drivers and safety marshals, and a special team is sent out on track to eradicate the issue. This requires the need for additional training for safety marshals or the addition of a team specific for managing these issues, however formula e stated in 2021 that at that point no crashed vehicle had ever shown a red light due to the strict regulations in providing optimum vehicle safety. (Franchescini, 2021). Another way the racing series can reduce their carbon footprint is with the use of carbon offsetting. It is defined as a process by which an organization or individual contributes to a scheme that is projected to remove carbon dioxide from the atmosphere (Adams, 2013). Companies such as Sustainable Travel International (STI) focus on a travel aspect of carbon offsetting. They calculate how the carbon footprint is affected by how people are travelling to and from events with regards to distance and

method of transport giving an overall cost to offset this footprint. Sustainable Travel International have helped individuals and businesses offset over 380,000 metric tons of CO2 emissions. Using (Myclimate, 2023) table 5-1 shows calculated results for travel emissions for 1 person going between each round of the series, accumulating a total of 4.366 Tonnes of CO2 emissions, Investing in Sustainable Travel International will have a significant impact on decreasing the carbon footprint of the series.

Table 5-1 - Emissions from travelling between rounds.

Flights	CO2 Emissions (Tonne)
Long Beach, CA to Atlanta, Georgia	1.1
Atlanta, Georgia to Orlando,Florida	0.334
Orlando, Florida to Englishtown, New Jersey	0.568
Englishtown, New Jersey to St. Louis, Missouri	0.533
St. Louis, Missouri to Seattle, Washington	0.967
Seattle, Washington to Grantsville, Utah	0.457
Grantsville, Utah to Irwindale, California	0.407
Total	4.366

6 Discussion

Throughout the report, the advantages and disadvantages of various energy carriers were discussed. The recommendation is to use synthetic fuels as they significantly reduce yearly emissions and maintain the excitement of the sport. Electric powertrain and hydrogen fuel cells eliminate the thrill factor that spectators crave, as evidenced by the difference in viewership between Formula 1 (70million per race (Statista, 2022)) and Formula E (20million per race (ABB Formula E, 2021)). Switching to electric or hydrogen powertrains would require extensive infrastructure changes which require a lot of time and money which synthetic fuels do not and therefore can be implemented sooner. Furthermore, if synthetic fuels are used no additional safety training will be required for the teams and staff. Summarising the findings that have been mentioned throughout the report a feasibility study has been made with 8 different criteria regarding the energy carriers. As can be seen in table 1 the synthetic fuel has proven superior not only overall but having a higher rating than the other fuels within all criteria's other than costs and the tail pipe emissions due to the slight release of CO2 emissions.

Table 6-1 - Feasibility study for energy carriers

Feasibility Criteria	Hydrogen Combustion	Hydrogen Fuel Cell	Electric Powertrain	Synthetic Fuel
Renewable	3	3	3	5
Efficiency	1*	4	5	4
Tail pipe Emissions	5	5	5	4
Production Emissions	3	3	1	5
Practicality in Filling	5	5	3	5
Infrastructure	3	3	3	5
Safety	3	3	3	5
Running Cost	1*	2	5	4
Spectators	5	1	1	5
Total	29	29	29	37

Key: 1 = Worst 5 = Best *No data

Circuit improvements should include installing solar panels to reduce both the racing series' and the circuit's carbon footprint. Sustainable transportation options, such as shuttle services and bicycle storage, should be provided for race teams, staff, and visitors. Carbon offsetting programs should be invested in to fund emission-reducing projects like reforestation.

7 Conclusion

To conclude, this report has critically analysed the advantages and disadvantages of alternative energy carriers. This has shown that although hydrogen combustion and fuel cells do not emit any emissions from their tailpipes its crucial as to what type of hydrogen is used to decide whether the fuel is net zero. The analysis has also proven that replacing the current energy carriers with hydrogen will increase the running costs for each team. When it comes to an electric powertrain there is much stipulation to the spectators not enjoying the sport as much. Electric powertrains have also shown that due to the low mileage within the racing series that to use an electric powertrain is not viable due to the amount of production emissions that are produced. Synthetic fuels however not only do they cost the same as current petrol prices they can also be used in vehicles without any need for technology changes, but synthetic fuels also have a carbon neutral title. When it comes to infrastructure around circuits dramatic changes will need to be implemented if hydrogen or electric was to be used with the extra training required as well as the installation of charging stations. Finally, a key investment that Formula Drift should consider is the use of carbon offsetting, allowing them to reduce their carbon footprint even more by just paying another company to reduce CO2 emissions.

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