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Sustainability Challenges in Industry

Contemporary Powertrain Design / ACHA6012

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1 Introduction

The world of Formula 1 racing, while celebrated for its technological advancements, also navigates a complex landscape of environmental challenges. This technical report looks into the multifaceted environmental issues associated with the sport, with a particular emphasis on the logistical hurdles inherent to its global nature. Formula 1's calendar spans continents, requiring the transportation of teams, equipment, and infrastructure across vast distances—a process that contributes significantly to the sport's carbon footprint. Additionally, the construction and maintenance of racetracks, along with the energy requirements for such large-scale events, present further environmental concerns.

As the world becomes increasingly conscious of environmental sustainability, Formula 1 faces the pressing need to reconcile its high-performance ethos with eco-friendly practices. This report aims to dissect these challenges through a comprehensive analysis, examining the carbon emissions from the extensive travel schedules, the environmental impact of race weekends, and the broader implications of such a globally dispersed event. Furthermore, it will explore the measures currently being undertaken by the sport to mitigate its environmental impact, from logistical optimizations to the introduction of sustainable technologies, and consider the future pathways towards a more sustainable model for Formula 1 racing. Through a detailed exploration of these dimensions, the report seeks to provide insights into the ongoing efforts and potential strategies for reducing the environmental footprint of this prestigious motorsport.

2 Overview of Formula 1

Formula 1 is currently the most popular form of motorsport in the world, with a cumulative audience of 1.54 billion over the 2022 season (AR1, 2023), featuring 24 races held in different countries all around the world. In recent years Formula 1 has also seen a surge in popularity after the inclusion of the Netflix series 'Drive to Survive' which has brought new eyes onto the race series and generated additional revenue, which has been increasing steadily with a third quarter revenue of \$887 Million in 2023, 24% up from the 2022 season (Cooper, 2023). The teams consist of hundreds of members, with over 800 people working for the red bull racing F1 team last year (Fageot, 2023), and up to 100 from each team attending each race weekend which puts into perspective the scale of infrastructure required to run just two cars.

Due to the popularity and revenue figures the sport has understandably come under some pressure in recent years amid climate concerns and resulted in Formula 1 setting a goal of being carbon neutral by the year 2030, an aim announced in 2019, However the global inclusion and popularity of the sport creates many logistical challenges when trying to push for a more environmentally friendly future for the sport.

3 Fuel

A large part of this goal revolves around fuel as the current cars use an 'E10' blend of 90% fossil fuel and 10% ethanol since being introduced in 2022, with the target being to implement a 100% sustainable fuel to be used in the F1 cars from 2026 onwards, developing this fuel in collaboration with natural gas company ARAMCO. F1's smaller feeder series' F2 and F3 made the step to use fuel containing 55% sustainable (bio-sourced) material (Straw, 2023), acting as somewhat of a test bed for the new biofuel before its full introduction into Formula 1 starting in 2026, when cars will run solely on this sustainable biofuel. F2 and F3 plan to follow this a year later, upping the 55% sustainable fuel to 100% in 2027.

Although these changes are absolutely beneficial to the environment, it is a smaller margin compared to other factors within the sport, looking at figure 1 only 0.7% (1795.86 tonnes) of CO₂ emissions came from the cars themselves across the season, where the primary attention seems to be placed in media and news however it is clear that more attention must be paid to the other factors which contribute a far larger amount to total emissions of the series. This reason does not detract from the importance of sustainable fuels within motorsport however when going into more detail it is overshadowed by the scale of emissions from the less visible sources such as logistics and travel.

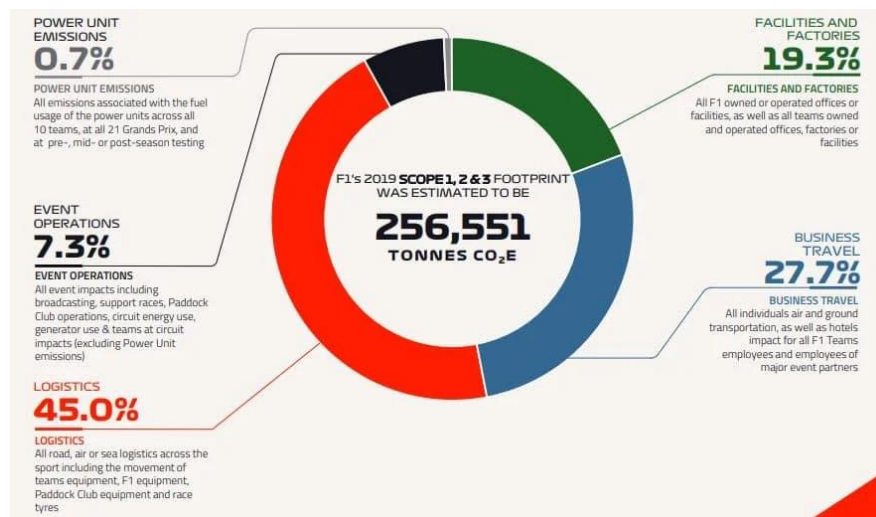


Figure 1: Formula 1 emissions (Formula 1, 2020)

Since 2014 the cars have utilised hybrid power units, which was the first step placed towards making the sport greener, and due this large attention already placed upon alternate fuel for the cars themselves this report will instead look deeper into the other areas that pollute more and are less well known, such as logistics and travel.

4 Logistics

When the climate pledge was introduced in 2019 F1 had a footprint of 256,551 tonnes of CO₂, with the vast majority of emissions however coming from logistics with 45% and business travel with 27.7% shown in figure 1. This is due to all teams being based in Europe and having to transport a large quantity of tools and equipment to each race, an example of this is F1's official logistics partner DHL transported 1540 tons of equipment, as well as 532 cars over a total distance of 74,500 miles in 2021 alone (Francks, 2023). This equipment is transported by land, air, and sea with the highest priority items such as cars and tools are transported via lorries if within Europe, or by air on large Boeing 747 aircraft, or newer Boeing 777 aircraft (Barretto, 2022). The 'less urgent' equipment such as furniture and catering equipment are transported via sea in around 120 shipping containers (Francks, 2023).

4.1 Shipping sector

As the shipping industry is utilised quite substantially in the transport of equipment to races, it was investigated more in depth to identify the issues and potential alternatives.

Although maritime transport is a relatively energy efficient method of transport and is responsible for over 80% of world merchandise trade by volume (UNCTAD, 2022), it is a large source of greenhouse gas emissions, with 1.076 billion tonnes of CO₂ emitted in 2018 alone which equated to 2.9% of global emissions from any source. Looking just at the EU shipping covered 3-4% of total EU emissions in 2021, equating to over 124 million tonnes of CO₂ (European Commission, n.d.). Looking at how heavily utilised this sector is globally not just in motorsport it beckons the question as to why more global effort is not directed towards reducing the environmental impact of the shipping industry.

One way to improve this sector is to look into alternate fuels to be used in the ships, however this comes with many challenges, as building new ship engines to run on sustainable fuels as well as providing sufficient reliable infrastructure is incredibly expensive. Retrofitting can be an alternative where an existing ship is modified in order to be able to run on sustainable fuels however this can still cost more than 30 million USD (Bourboulis et al, 2021), therefore this option in conjunction with building new ships to be able to run on zero-emission fuels provide a positive change that has potential to make a large impact on the reduction of greenhouse gas emissions.

4.1.1 Getting to zero coalition

The 'Getting to Zero Coalition' is an alliance of more than 200 organisations within the maritime, energy, infrastructure and finance sectors committed to pushing zero emission vessels into operation by 2030 with a goal for full decarbonization by 2050 (Global Maritime Forum, n.d.). Figure 2 shows the planned introduction of newbuild and retrofit zero emission vessels, starting in 2030 and scaling rapidly towards the goal of full decarbonization by 2050.

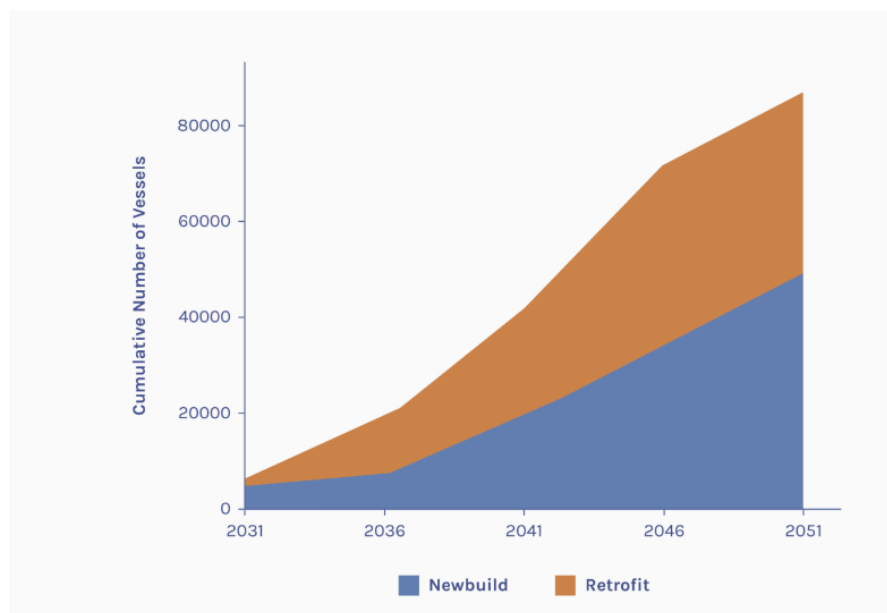


Figure 2: Planned 'Getting to Zero' program (Global Maritime Forum, n.d.)

This ratio of newbuild and retrofit vessels being utilised provides a more flexible and cost-effective way of reaching this ambitious goal, another key point is how the proposed methanol and/or LPG engines can be retrofit to run on a second fuel when necessary, increasing the feasibility of the idea and reducing the demand on the required infrastructure.

4.1.2 Shipping Sector Overview

After investigating how this sector is utilised in Formula 1 it is clear that there should be significant focus placed on decreasing the use of transport by sea, if possible, as the primary future development projects are quite far off in the future and due to the scale of the vessels used it would be very expensive to make any changes being that short term or long term. However the plans to retrofit sustainably fuelled engines are promising and provide a future goal for the sector that would greatly reduce the environmental damage.

4.2 Aviation Sector

Looking next at the aviation transport sector which is responsible for the transport of the 'higher priority' equipment in Formula 1, most importantly of which being the cars. As mentioned, the most common airborne overseas transport for this is the Boeing 747 and has been for many years, only recently introducing the Boeing 777 to slowly take over the 747's position. The 747 emits up to 8.4 tonnes of CO₂ per flight hour (golden epaulettes, n.d.), whereas the 777 allows for 30% lower fuel consumption and emissions over the same distance (Boeing, 2022).



Figure 3: Formula 1 Car being loaded onto a Boeing 747 (DHL, n.d.)

The International Council on Clean Transportation (ICCT) analysed the CO₂ emissions of each aircraft class and use and found that dedicated freighters, which would be used for the transport of Formula 1 equipment, contributed 70 million tonnes of CO₂ in 2018 and 66 million tonnes in 2019, shown in figure 4.

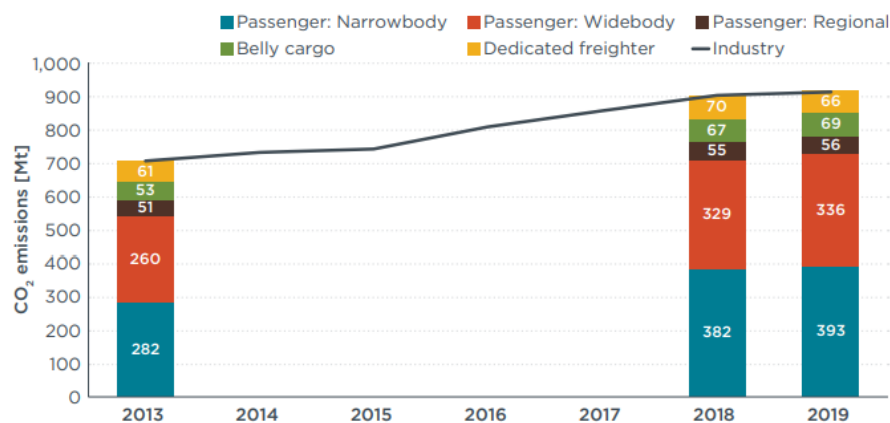


Figure 4: CO₂ emissions of the aviation sector (ICCT, 2020)

Although not as high as the shipping sector, each team transports on average between 45 and 55 tonnes of equipment which for the ten teams on the grid equates to potentially over 500 tonnes of cargo (Francks, 2023), as the Boeing 777 freighter has a maximum freight capacity of 100 tonnes (ANA Cargo, n.d.) a minimum of 5-6 Boeing 777 planes would be required for an overseas race weekend which is equal to over 35 tonnes of CO₂ per flight hour for the entire grid, even in the more efficient 777 jet.

4.2.1 Rolls Royce UltraFan

With the introduction of alternatively fuelled cargo aircraft such as hydrogen being unlikely for 15-20 years (Parkes, 2023), looking instead to improve the existing technology and utilise sustainable fuel may be a better option to reduce emissions until a fully fledged alternate fuel option is possible. Rolls Royce are pioneering this technology with the development of their UltraFan turbofan engine, which is 25% more efficient than the Rolls Royce Trent engine which in its latest iteration is the most efficient large aero engine flying today (Rolls Royce, n.d.). One important factor is that the UltraFan is designed for the future and will be ready to run on 100% sustainable aviation fuel (SAF) from day one of service, and the first successful demonstrator run of the UltraFan was run on 100% SAF, showing that this technology is not far from its introduction.

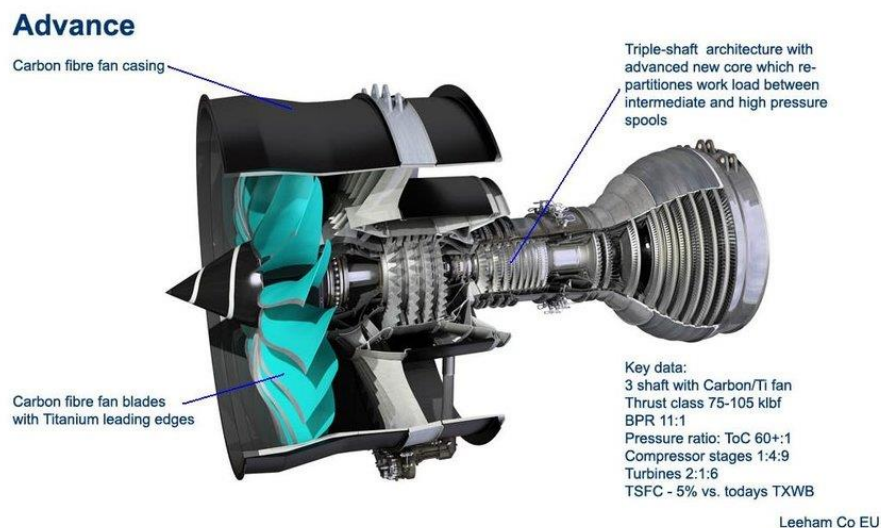


Figure 5: Rolls Royce UltraFan Turbo fan engine (Rolls Royce, n.d.)

4.2.2 Aviation sector overview

Looking at the aviation sector as a whole it is clear that there is significant opportunity for improvements in environmental protection in the near future, with the introduction of highly efficient aircraft jet engines running on solely sustainable fuels. Looking forward in future seasons this method of transporting equipment although potentially more expensive for the teams and/or company it would highly reduce the carbon footprint of the Formula 1 series. One further key factor when looking carbon emissions from the aviation sector in particular is that it is not just used in Formula 1 for the transport of equipment but also the vast number of staff working for each team who have to travel around the globe for each race, and also the spectators. These factors reinforce how reducing emissions from this sector will have a large effect across the sport from cars to team equipment to spectators.

5 Sustainable Aviation Fuel (SAF)

Sustainable Aviation Fuel (SAF) is a certified jet fuel manufactured using renewable “feedstock” such as agricultural waste, plant oils and used cooking oil. This form of jet fuel can reduce CO₂ emissions by 80% compared to conventional jet fuel and when considering that 2-3% of global greenhouse gas emissions come from air transport (Airbus, n.d.), this has potential to make a large impact on the reduction of total emissions.

5.1 Benefits of SAF

One of the key benefits of SAF is its ability to be used as a drop-in fuel replacement, with the strict approval process ensuring it is close to chemically identical to conventional jet fuel allows its use in existing aircraft engines and can also be mixed with standard jet fuel (ASTM, 2023). This allows it to be more effectively ‘phased in’ even if the infrastructure is not yet on par with the existing manufacture of conventional jet fuel and requires no adaptation to the aircraft or fuel supply infrastructure.

Some other benefits of SAF include the very low level of sulphur and aromatic content produced, along with studies finding that particulate matter emissions when cruising are reduced by 50-97% with the highest reductions at lower engine power such as taxiing which results in lower damaging effects to local air quality surrounding airport (Durdina et al, 2021).

5.1.1 SAF Production Sources

On key benefit of SAF as an alternate fuel is the vast number of potential sources of which it can be produced, these can be seen in table 1 on the following page.

Table 1: Sources for SAF production (US Department of Energy n.d.)

SAF Production Pathways				
Pathway	Approved Name	Blending Limitation	Feedstocks	Chemical Process
Fischer-Tropsch (FT) Synthetic Paraffinic Kerosene (SPK)	FT-SPK, ASTM D7566 Annex A1, 2009	50%	Municipal solid waste, agricultural and forest wastes, energy crops	Woody biomass is converted to syngas using gasification, then a Fischer-Tropsch synthesis reaction converts the syngas to jet fuel. Feedstocks include various sources of renewable biomass, primarily woody biomass such as municipal solid waste, agricultural wastes, forest wastes, wood, and energy crops. ASTM approved in June 2009 with a 50% blend limit.
Hydroprocessed Esters and Fatty Acids	HEFA-SPK, ASTM D7566 Annex A2, 2011	50%	Oil-based feedstocks (e.g., jatropha, algae, camelina, and yellow grease)	Triglyceride feedstocks such as plant oil; animal oil; yellow or brown greases; or waste fat, oil, and greases are hydroprocessed to break apart the long chain of fatty acids, followed by hydroisomerization and hydrocracking. This pathway produces a drop-in fuel and was ASTM approved in July 2011 with a 50% blend limit.
Hydroprocessed Fermented Sugars to Synthetic Isoparaffins	HFS-SIP, ASTM D7566 Annex A3, 2014	10%	Sugars	Microbial conversion of sugars to hydrocarbons. Feedstocks include cellulosic biomass feedstocks (e.g., herbaceous biomass and corn stover). Pretreated waste fat, oil, and greases also can be eligible feedstocks. ASTM approved by ASTM in June 2014 with a 10% blend limit.
FT-SPK with Aromatics	FT-SPK/A, ASTM D7566 Annex A4, 2015	50%	Same as A1	Biomass is converted to syngas, which is then converted to synthetic paraffinic kerosene and aromatics by FT synthesis. This process is similar to FT-SPK ASTM D7566 Annex A1, but with the addition of aromatic components. ASTM approved in November 2015 with a 50% blend limit.
Alcohol-to-Jet Synthetic Paraffinic Kerosene	ATJ-SPK, ASTM D7566 Annex A5, 2016	50%	Cellulosic biomass	Conversion of cellulosic or starchy alcohol (isobutanol and ethanol) into a drop-in fuel through a series of chemical reactions—dehydration, hydrogenation, oligomerization, and hydrotreatment. The alcohols are derived from cellulosic feedstock or starchy feedstock via fermentation or gasification reactions. Ethanol and isobutanol produced from lignocellulosic biomass (e.g., corn stover) are considered favorable feedstocks, but other potential feedstocks (not yet ASTM approved) include methanol, iso-propanol, and long-chain fatty alcohols. ASTM approved in April 2016 for isobutanol and in June 2018 for ethanol with a 30% blend limit.
Catalytic Hydrothermolysis Synthesized Kerosene	CH-SK or CHJ, ASTM D7566 Annex A6, 2020	50%	Fatty acids or fatty acid esters or lipids from fat oil greases	(Also called hydrothermal liquefaction), clean free fatty acid oil from processing waste oils or energy oils is combined with preheated feed water and then passed to a catalytic hydrothermolysis reactor. Feedstocks for the CH-SPK process can be a variety of triglyceride-based feedstocks such as soybean oil, jatropha oil, camelina oil, carinata oil, and tung oil. ASTM approved in February 2020 with a 50% blend limit.
Hydrocarbon-Hydroprocessed Esters and Fatty Acids	HC-HEFA-SPK, ASTM D7566 Annex A7, 2020	10%	Algal oil	Conversion of the triglyceride oil, derived from <i>Botryococcus braunii</i> , into jet fuel and other fractionations. <i>Botryococcus braunii</i> is a high-growth alga that produces triglyceride oil. ASTM approved in May 2020 with a 10% blend limit.
Fats, Oils, and Greases (FOG) Co-Processing	FOG Co-Processing ASTM D1655 Annex A1	5%	Fats, oils, and greases	ASTM approved 5% fats, oils, and greases coprocessing with petroleum intermediates as a potential SAF pathway. Used cooking oil and waste animal fats are two other popular sources for coprocessing.
FT Co-Processing	FT Co-Processing ASTM D1655 Annex A1	5%	FT biocrude	In association with the University of Dayton Research Institute, ASTM approved 5% Fischer-Tropsch syncrude coprocessing with petroleum crude oil to produce SAF.

As shown in table 1 SAF can be produced from a very large range of waste products, however the limiting factor of the usability is the “blending limitation” which refers to the maximum blend of SAF to conventional ‘Jet A’ fuel permitted and meets the standards for jet fuel. The most commonly used standards are American Society for Testing Materials (ASTM) standards number D1655 and DEF STAN 91-91, which set requirements for properties such as composition, volatility, fluidity, combustion and corrosion (IATA, 2020).

Shown on the fifth row of table 1 is alcohol to jet (ATJ), which describes the process of the conversion of alcohol to an alternative jet fuel blendstock, based around catalytic steps used by the existing petrochemical industry. As is the case with other SAF sources it provides a near term opportunity for existing alcohol producers and infrastructure to enter the aviation sector and make an impact to reduce emissions globally (Geleynse et al, 2018).

6 Conclusion

After analysing the sources of emission and environmental damage that Formula 1 creates, it is clear that more focus must be placed on improving the travel and logistics procedures surrounding races, with a combined 72.7% of greenhouse gas emissions coming from these sectors alone. The two main sectors analysed being the shipping and aviation sectors were found to be incredibly damaging overall, however some key changes would result in the overall footprint of Formula 1 to be far smaller.

The shipping sector was found to be a main emitter of greenhouse gases however the projects to reduce this are incredibly expensive and would require vast changes in infrastructure which isn't realistic for a near term goal. The aviation sector was found to be further ahead in its introduction of alternate fuels and more efficient aircraft, with the introduction of highly efficient engines like the Rolls Royce UltraFan working in conjunction with Sustainable Aviation Fuels (SAF) which have the potential to greatly reduce overall travel and logistics emissions.

Overall from the analysis completed, the suggested method in the near future to make the largest impact would be to reduce the use of the shipping sector, and instead utilise the aviation sector when moving infrastructure and equipment overseas as long as the fuels used are from sustainable origin. Moving forward with the potential 'decarbonization' of shipping vessels, the shipping transport sector can be more utilised however this goal lies further in the future and requires far more funding in order to bring the idea into fruition.

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