# **Investigating Formula One's 2030 Sustainability Initiative**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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**STS Research Paper**

## Introduction

With the fastest speeds, loudest engines, and most storied racetracks, Formula One (F1) is the pinnacle of motorsport and has been since 1950. However, as the sport enters its eighth decade, there have been calls for F1 to improve its sustainability. In response to this, F1 has made sweeping changes to its technical regulations, including a swap to turbo-hybrid V6 engines (Collins, 2014). Furthermore, F1 has committed to the ambitious goal of becoming net carbon zero by 2030 (F1 Sustainability Strategy, 2019). However, with this deadline quickly approaching less than seven years away, F1 still requires improvement if it is going to meet this goal. Therefore, this paper will attempt to determine if F1 is making meaningful progress towards its net carbon zero goal by 2030. To properly analyze if F1 is making actual progress towards its goal, the technological fix framework will be used to identify if the actual problem is being addressed.

## Research Question and Methods

Although Formula One (F1) has been publicizing their goal of becoming carbon zero in 2030, it is yet to be determined if F1 is on pace to meet that goal. Secondary data analysis is employed to see if F1 is on track to meet their goal in three main areas: alternative fuels, battery materials, and logistics. Keywords guiding the analysis are Formula One, logistics, lithium mining, biofuels, and sustainability. The analysis consists of investigating the use of alternative fuels in F1 power units, battery production, and F1's logistics within the technological fix framework.

## Background Information

F1 is an open development racing series, which means that teams are considered "constructors" who each build their own car to compete each year. The cars must adhere to a set of rules called a "formula", which is where the name of the series is derived from. F1 constructors are a combination of car manufacturers, including Ferrari, Mercedes, and McLaren, as well as private teams including Williams and Haas. Currently, there are 10 teams on the grid, with the space to expand to 13. Each team enters two cars for each 8 month long championship, which contains a 20-25 race schedule. Each race awards points towards the championship. At the end of the season, the driver with the most points is awarded the World Driver's Championship, and the constructor with the most points is awarded the World Constructor's Championship (F1 Chronicle, 2022).

Team operations and expenses in F1 are unlike any other racing series in the world. Although there was a spending war between top constructors, a budget cap was introduced in 2021 to encourage parity between teams. For the 2023 season, this is $135 million, with some exceptions allowed for uncapped spending (Beaver, 2022). This cap includes money spent both on research, development, and fabrication at constructors' factories, and on operations at races. At the factory, teams spend the majority of their budget on research and development. This includes countless engineers designing the car and testing its components, as well as the manufacturing of the cars and engines themselves. In order to reduce costs, smaller teams will purchase engines from larger teams (Motorsport.com, 2022). At the race track, teams must purchase specialized racing equipment like tires and fuel which have been specifically engineered to meet the rigors of F1 racing. Additionally, teams set up mobile structures as their base of operations as well as a space to entertain wealthy sponsors. Finally, they must pay for logistics companies to transport everything all around the world between each race (Motorsport.com, 2022).

Perhaps the most visible and oldest sustainability effort in F1 are the recent engine regulations. In 2014, F1 transitioned from a V8 engine to a V6 hybrid power unit (Collins, 2014). This move was designed to make F1 more eco-friendly, as it requires much less fuel to complete a full race. Furthermore, F1 has announced updated regulations for the 2026 season. These power units will be required to finish the same race distance on 30% less fuel. Additionally, the electric capacity of the engine will be increased, and it must entirely run on sustainable fuel (Kanal, 2022). However, the greatest need for improvement in F1's sustainability does not concern what is on the track, but what is off of it. Travel and logistics are the two biggest producers of F1's carbon emissions. Business travel produces 27.7% of the emissions, and logistics produces 45% of the emissions (F1 Sustainability Strategy, 2019). This is due to the large number of personnel and cargo transported to each race.

## **STS Framework**

F1 racing has both a large economic and environmental impact on the world due to the size of each event and their widespread locations. For closed road circuits, often located in remote areas, F1 races offer the chance to attract a global audience and economic growth for the area. At urban street circuits, tourists flood hotels and restaurants while local traffic is halted by a race track dropped in the middle of a city. Additionally, the environmental impact of F1 is quite vast. In 2019, F1 produced 256,551 tons of CO2 emissions, equivalent to that of a small country (European Commission, 2022).

This paper analyzes the research question using multiple perspectives of the technological fix framework. The first is Allen Weinberg's perspective on how a technological fix can solve societal problems (Seabrook, 2022). For example, F1 can alleviate its sustainability problem by using carbon neutral biofuel to power its race cars and transport vehicles. Additionally, it can incorporate more electric components in its race cars or use electric transport for land-based logistics. However, the perspective of Byron Newberry will be used to challenge Weinberg's perspective. Newberry argues that technology is a band-aid, and that a technological fix often is an "easy way out" and "shifts the locus of the problem" (Newberry, 2005). Applying Newberry's perspective to the topic at hand, the sustainability of biofuels and batteries are called into question.

Finally, the perspective of Timothy LeCain organizes the technological fix into three categories: the transformational fix, the relocational fix, and the delaying fix (LeCain, 2004). LeCain argues that although the transformational and relocational fixes are effective at solving a problem, they often lead to unintended consequences from which the third type of fix occurs: the delaying fix. This simply transfers the problem to a new generation, rather than solving it completely.

For the most part, the authors involved agree with each other. All three authors agree that technological fixes can solve surface level problems, although Weinberg neglects to extend his analysis further than a superficial stage. Both authors who drill into the true root of the problem, however, agree that technological fixes can lead to solutions which alleviate symptoms but do not solve the problem itself. Both Newberry and LeCain argue that technological fixes ultimately transfer the burden of the problem away from its original source. By and large, authors especially agree with this perspective when talking about technological fixes related to the environment.

LeCain alludes to this when he asks the question if “eco-efficiency” can be achieved with a true fix, or if it is a zero-sum game where one area of the environment suffers due to a fix in another (Rosner, 2004).

The analysis uses the technological fix in concert with secondary data analysis to determine if F1 is meeting its sustainability goal of becoming net carbon zero by 2030, or if it is using a technological fix to shift the problem away from itself. The framework will view both the technology used to reduce carbon emissions, as well as its role in the larger scope of its contribution to F1’s sustainability initiative. The goal of this approach is to determine how the technology fits into F1’s strategy to achieve net carbon zero emissions by 2030 as well as its efficacy and viability.

## Results and Discussion

F1 is making significant progress in some areas towards their goal in becoming net carbon zero by 2030 but lagging in other areas. Perhaps their most successful effort is developing alternative fuels for the cars’ power units. These alternative fuels are net carbon zero and are already in a long-term testing program in cooperation with F1’s feeder racing series. Additionally, the batteries used by F1 power units are getting upgraded to provide more electrical power for the new engine regulations, although concerns have been raised about the environmental considerations of their production. Finally, F1 is making strides towards integrating biofuels in its land-based logistics effort, but does not appear to have a plan for other modes of freight.

### Alternative Fuels

Although alternative fuels are not currently used in F1 today, progress is being made to achieve their use. During the current 2023 season, F1 powers its cars with E10 fuel. E10 fuel is a low-level blend of ethanol which mixes 10% ethanol with 90% gasoline. The ethanol is created from various plant materials known as biostocks. However, according to the United States Department of Energy, it does not qualify as alternative fuel (U.S. Department of Energy, n.d.). Although there is debate on the degree of ethanol's sustainability depending on its source, F1's Chief Technical Officer Pat Symonds claims the E10 used today is "entirely sustainable" (Barretto, 2022). The F1 Technical Regulations - published by the sport's governing body, the Federation Internationale de l'Automobile (FIA) - specify that "advanced sustainable ethanol" must be used, meaning the ethanol is synthesized from non-food biomass, municipal waste, or a carbon capture scheme. The regulations also specify the ethanol must achieve a 65% reduction of greenhouse gases (GHGs) compared to fossil-derived gasoline (Federation Internationale de l'Automobile, 18 February 2022). For example, Ferrari's ethanol is obtained from sugarcane bagasse, a byproduct of sugar production, and generates 86% less emissions than fossil fuels. Additionally, ethanol produced from sugarcane bagasse is considered a second generation biofuel because it uses a waste product. Sugarcane bagasse is the leftover biomass from sugarcane processing, therefore the biomass used is not grown specifically for ethanol production, but primarily for food (Samora & Slattery, 2021). Therefore, the ethanol complies with FIA regulations.

Looking to the future, F1 has developed plans for a new fuel to be used starting in the 2026 season. This fuel will achieve the FIA's goal of being net carbon zero, as the carbon used to produce the fuel will equal the carbon emitted from every internal combustion engine (ICE) in all of the cars. The fuel will be a "drop-in fuel," which requires no change to the ICE's architecture (Benson, 2022). Currently, advanced synthetic fuel is being used in F1's feeder series, Formula Two (F2) and Formula Three (F3). The fuel is a mix of 55% synthetic, sustainable gasoline and 45% fossil-derived gasoline. Wind and solar powered electrolysis produce the hydrogen used in the fuel, and the carbon is derived from non-food plants or waste (Gitlin, 2023). As a result, the synthetic part of the fuel is net carbon zero, as no carbon is used to produce the hydrogen and the carbon has been derived from a renewable source. In 2025, the carbon will be produced from carbon capture, where the carbon is derived from atmospheric carbon dioxide. This synthetic gasoline with carbon capture will make up 100% of the fuel in 2027 (Gitlin, 2023).

Synthetic gasoline is regarded as sustainable by researchers. Existing carbon in the atmosphere is reformed into synthetic gasoline using Fischer-Troph synthesis (Dimitriou et al, 2015). However, synthetic gasoline is not yet commercially viable. Currently, carbon produced from carbon capture costs \$400-\$800 per ton, which results in an oil price of \$200-\$300 per barrel, which is twice the cost of fossil-derived gasoline (Gitlin, 2023). Therefore, more research on carbon capture technology is needed to produce commercially viable synthetic gasoline (Dimitriou et al, 2015). However, because of F1's budget and willingness to contribute to innovation, it meets their needs despite the high price.

The use of alternative fuel in F1 power units is a useful technological fix with regards to reducing tailpipe carbon emissions, but it fails as a technological fix when applied to F1's carbon emissions problem as a whole. This is because its role as F1's main net carbon zero initiative represents an organizational problem with F1 and an attempt to divert attention from the larger carbon problem in F1. According to Allen Weinberg, the technological fix occurs when technology is used to fix a problem usually solved by other social processes, including organization (Newberry, 2005). In this instance, F1 should utilize better organization of their resources to combat their carbon emissions in a more effective manner.

The carbon emissions of F1 race power units only represents 0.7% of carbon emissions, yet it is the sustainability initiative which has been the most publicized and the only one with a long-term testing and roll-out plan (F1 Sustainability Strategy, 2019). Therefore, the use of technology and resources to tackle this problem instead of another sector of carbon emissions, such as logistics, which contributes 45% of F1's emissions, represents a disconnect between the most efficient solution and the attention applied to it. Although F1's proposed solution appears to be sound and has a well thought out plan for implementation, their efforts should be focused on the areas of carbon production that lead to a greater portion of their emissions.

Furthermore, this technological fix is being used to greenwash F1. Greenwashing occurs when companies exaggerate their sustainability efforts in order to appear more appealing to consumers (Gibbens, 2022). By publicizing their efforts on tackling a small-scale problem, a company can market themselves as sustainable to consumers while neglecting to tackle larger problems. F1 is diverting most of their sustainability effort into synthetic fuel for power units. By publicizing their use of alternative fuels as the solution to their carbon emissions, F1 is changing the problem from one of science and the environment to a social problem of public perception. If F1 uses this technological fix to appear green and cut out emissions from their cars, the most visible part of their product, they will face less pressure from external sources to reduce larger carbon emissions in less visible areas, including logistics.

Although F1's effort to use alternative fuels in their race car power units is admirable, it does not address the root of their problem: carbon use is pervasive throughout F1 and is used on a much larger scale in other areas of their operations. Even if these efforts do succeed, they only serve to solve an extremely small part of the problem. F1's development of synthetic race fuel does not address the root of the problem – the geographic spread of F1's races produce large amounts of carbon during the transport of personnel and supplies to each race. It would behoove F1 to develop solutions, technological or not, to larger areas of carbon production in their operations, such as logistics and travel. Alternatively, F1 could divert some effort from sustainable race fuel development to other carbon emission reduction methods in order to correct the organizational problem and deliver a technological fix that serves the greater mission of becoming net carbon zero by 2030.

**Battery Materials**

The battery used in F1 cars is formally referred to as the power unit energy store. Its critical component is a 20 kilograms lithium-ion battery solution (Formula 1 Engine Facts). However, for the new 2026 power unit regulations, the battery solution will almost double to 35 kilograms. The targeted electrical power created by the power unit is 350 kilowatts, almost tripling the 120 kilowatts of electrical power created by the old power unit (Federation Internationale de l'Automobile, 16 August 2022). During the season, constructors will be limited to three power units per car without being subjected to penalties (Kanal, 2022). This restriction means the power unit manufacturers will build a minimum of 60 power units per season, meaning that F1 requires at minimum 2100 kilograms of lithium. Additionally, the power units require other rare materials to properly function, such as cobalt. Cobalt extends the life of the battery and reduces flammability. In F1, teams are limited to using 10% cobalt concentration in electrical machines but are allowed to increase that limit to 49% if all end-of-life cobalt is recycled. Additionally, any cobalt used must come from an "ethical source." However, an ethical source is not defined in the regulations (Federation Internationale de l'Automobile, 2022).

Lithium is predominately mined using two methods: open pit mining, and evaporation. Lithium is extracted from clay dug out of the ground, forming a large pit. The clay is then mixed with sulfuric acid to extract the lithium, creating harmful waste. This waste then has the potential to contaminate groundwater in the surrounding area. Additionally, large quantities of water are used during this process, straining local ecosystems. Evaporation is a much more sustainable method, as it obtains lithium from a salty brine. This brine can be created from ocean water, which provides an abundant source for production. The energy used comes from the sun, which evaporates large pools of the brine to extract the lithium. However, there are concerns with this method's land use, as it requires a very large area to construct the evaporation pools (Penn et al, 2021).

Although lithium mining presents environmental hazards, cobalt mining exposes many people to dangerous health conditions. 75% of the world's cobalt reserves are located in the Democratic Republic of the Congo (DRC). Although cobalt is toxic to touch and breathe, "artisanal" miners use primitive tools such as pickaxes to dig in and around industrial mines, mixing with the formal cobalt supply chain (Gross, 2023). The spillage from ore bags and residue from processing leads to the accumulation of ore-containing dust, causing oxidative stress and DNA damage (Banza Lubaba Nkulu et al, 2018). Unfortunately, it is difficult to separate industrial and artisanal mining because they occur so close to each other. As a result, it is difficult to ensure that cobalt in the DRC is mined ethically (Gross, 2023).

Although these concerns do not relate to carbon directly, they do contribute to F1's overarching goal of sustainability, and it would be remiss to not discuss them when determining the validity of F1's sustainability efforts. Destroying ecosystems and endangering the health of thousands is not a viable way to reduce carbon emissions. However, F1 suppliers seem to be making an effort to avoid these pitfalls and produce sustainable materials for F1 cars. One such company, Saft, supplies batteries to F1 teams for use in power units. Their sustainability code not only requires them to comply with applicable laws but ensure the compliance of contractors and subcontractors. Additionally, Saft follows Organisation for Economic Co-operation and Development (OECD) guidelines for due diligence for purchasing metals. Furthermore, Saft's Fundamental Principles of Purchasing forms an agreement between Saft and suppliers, who are required to agree to conduct business with Saft. The agreement stipulates various responsibilities in the areas of social responsibility, compliance with ethical principles, and environmental responsibility (Our Sustainability Global Approach, 2023).

Although the use of batteries results in no carbon emissions at the tail pipe, which completely aligns with F1's goal of becoming net carbon zero, external factors must be considered when discussing battery production. First of all, carbon emissions from manufacturing must be considered, as to be net carbon zero, all energy used to produce the battery must be carbon zero. Secondly, there are extreme environmental and human factors involved in lithium and cobalt mining, jeopardizing the health and wellness of ecosystems and people globally. Although it appears F1 suppliers are making an effort to eliminate these concerns, it is not yet proven if they are doing it, or can by 2030.

The batteries for the F1 power unit represents a technological shortcut, when a technological solution only alleviates the symptoms, not the cause, of the problem (Newberry, 2005). Although energy from batteries will not have any emissions at the tail pipe, there are still carbon emissions being produced during the production of the batteries. F1 does not appear to have a plan to tackle the carbon emissions of its battery suppliers. Notably, Saft's sustainability approach outlines a 4% year over year reduction in carbon emissions, which will not be net carbon zero by 2030 (Our Sustainability Global Approach, 2023). Thus, the battery produces "clean" energy, but not over the entire life cycle of the product. Additionally, this technological shortcut creates more problems outside the scope of carbon emissions. Mining for rare earth elements has a negative impact on the environment, and even puts the health of miners in danger. Given the nature of battery production as a combined technological, environmental, and social problem, represents the inherent incompatibility between a technological fix and the problem it seeks to solve (Newberry, 2005).

Technological fixes applied to mining are not a new concept. Around the turn of the 20th century, copper mining and processing in the Smoky Mountains region in Tennessee, North Carolina, and Georgia produced thick smoke from smelting containing harmful sulfur dioxide. To alleviate this problem, engineers and chemists used transformational and relocational technological fixes in order to comply with an injunction requiring them to remove sulfur dioxide from smelting smoke. First, the transformational fix was to extract the sulfur dioxide and repurpose it into superphosphate fertilizer. Next, the relocational fix spread the fertilizer to crop land across the Smoky Mountains region. These fixes had positive short-term effects, as the fertilizer allowed more crops to be harvested, and copper mining and processing could continue. However, the professionals who designed the system neglected to consider the environmental effects of the fertilizer. When the fertilizer ran off into waterways, it fed algae which overtook the local ecosystem and choked the oxygen out of the system, leading to the death of most other aquatic life. This is where the delaying fix comes in, as the smelting problem ultimately caused disaster in local aquatic life in the future (LeCain, 2004).

Like copper processing in the Smoky Mountains, F1's use of lithium and other rare earth metals in their power unit batteries is an example of a delaying fix, as they are not considering the effects of lithium mining into their sustainability outlook. The batteries themselves are a transformational fix, as the energy required to propel the car is being changed from fossil fuel energy to energy regenerated through braking and the exhaust system. However, F1's application of the batteries is a delaying fix because they are pushing their sustainability problem from on-track carbon emission to unsustainable mining practices. This problem is compounded as F1 is pushing the problem away from their subject of expertise. F1 is moving the problem away from racing, an area they are familiar with, to an unfamiliar area of industrial mining. The root of F1's problem is not changing to hybrid racing or electrified racing that requires batteries, but generating sustainable racing which will result in net carbon zero emissions. By applying the batteries as a technological fix, F1 is transferring the problem down the line to lithium mines across the world. As a result, they are creating more widespread problems in an area which they are unfamiliar with and have less ability to solve any problems that arise. Therefore, F1's use of a technological fix with their batteries may lead them to become more unsustainable holistically and transfer carbon production to mines across the world, even if it reduces carbon emissions on their cars at the tailpipe.

**Logistics**

In a way, logistics is what separates F1 from every other racing series in the world. No other series races in as diverse locations as often as F1 does. The 2023 season schedule consists of 23 races across five continents (F1 Schedule 2023 – Official Calendar of Grand Prix Races). No racing series combines the far geographic reach and frequency of competition. To accomplish this task, a massive logistics effort is needed for every race. This effort, often referred to informally as the "F1 Circus," requires 2000 metric tons of cargo on average to be shipped per race. On average 600 metric tons are shipped via air, 1000 metric tons by sea, and 400 metric tons via truck (Wieczorek, 2018). During the main part of the season, most of the races take place in Europe. From Round 7 in Monaco to Round 15 in Italy, 8 out of the 9 races take place in Europe (F1 Schedule 2023 – Official Calendar of Grand Prix Races, n.d.). For this part of the calendar, most cargo is delivered by truck. However, the overseas legs of the trip present a greater logistical challenge. Essential parts, including electronics, IT systems, and car components are shipped via air freight. Non-essential standard components, such as garage equipment, are shipped via sea freight. Each team has five sets of these components which rotate. The first set is shipped to the first overseas destination. After the race is complete, it is sent to the sixth overseas destination. The second set is first shipped to the second overseas destination, then directly to the seventh, and so on (Wieczorek, 2018).

To reduce truck freight emissions, F1 is trialing biofuel in its cargo trucks. For the last three European rounds of the 2022 season, Mercedes AMG's 16 cargo trucks were powered with HVO 100, a biofuel derived from vegetable oils, fats, and waste oils. 98.6% of the 1400 kilometer journey from Belgium to the Netherlands, and then onto Italy was powered by HVO 100. Due to supply issues, the trucks ran on regular diesel for the last 20 kilometers. As a result, 44,091 kilograms of carbon dioxide was saved, reducing emissions by 89% (Mercedes Report 89% Reduction in CO2 Freight Emissions after Spa-Zandvoort-Monza Biofuels Truck Trial, 2022).

The production viability of hydrotreated vegetable oil (HVO) is promising for its widespread use in F1 logistics by 2030. HVO 100 has a technology readiness level (TRL) of 9, meaning that it is a proven fuel currently in operation. As it is more developed than its competitors by virtue of a high TRL, it is a likely candidate for integration in F1's logistical operations in the future (Paris et al, 2021). Furthermore, the ability of HVO to act as a drop-in fuel increases its likelihood for its use. This characteristic allows HVO 100 to be used in existing engine systems without changing the engine mechanics. HVO reduces carbon and hydrocarbon emissions, especially at low to medium loads. Additionally, engine efficiency is relatively unaffected. However, NOx emissions are shown to increase slightly compared to standard diesel fuel, leaving room for improvement in development (d'Ambrosio et al, 2022). Unfortunately, the economic viability of HVO 100 is not yet realized. It will only be cheaper than diesel in 2030 if diesel prices rise to €150 per barrel. These findings indicate that on a macro scale, the economic viability of HVO 100 is low. However, for F1's purposes of meeting their goal on a private scale, it presents a possible avenue for carbon reduction by 2030.

Unfortunately, F1 cannot rely on trucks for all of their logistics needs. When the championship moves overseas, cargo must be shipped via air freight. Out of air, land, and sea-based cargo it is the heaviest polluter by far. It produces over 32 times more t/tkm of carbon (metric tons of carbon per metric ton of cargo kilometer) than truck transport, and almost 80 times more t/tkm of carbon than sea transport. (Greene, n.d.). As of now, F1 does not have any public initiatives to decrease carbon consumption for air freight.

A possible avenue for F1 to improve their carbon emissions with respect to air freight by 2030 is sustainable aviation fuels (SAFs). Unfortunately, SAFs are currently in limited supply. Only two plants in the world produce SAFs, one in the United States and one in Europe (Gelles, 2023). However, the outlook is good for future SAF production. SAFs have a large basket of feedstock options, including byproducts and wastes which reduce carbon impacts. Additionally, SAFs can also be produced from carbon capture and hydrogen produced from electrolysis. Unfortunately, roughly two and a half times the energy is needed to create the required SAF energy, all of which must come from carbon zero sources in order to meet the net carbon zero goal. The viability of SAFs are bolstered by large scale interest in their research and development. The United States government wants SAFs to meet 100% of American jet fuel demand by 2050. The intermediate goal for 2030 is for 3 billion gallons of SAFs per year to be available, indicating a strong chance of viability for F1's use at the 2030 deadline.

Sea freight is the most efficient method of transporting F1 cargo. However, it has a very low speed compared to other methods which require multiple sets of equipment to be produced and used. Although F1 currently has no public plans to improve carbon usage with regards to their sea freight, Extreme E, another racing series sponsored by the FIA, currently is making big strides towards reducing their carbon consumption. Extreme E refurbished a former British ship, the St. Helena, to serve as their mobile base of operations for their global schedule. The St. Helena transports all of the cars and equipment necessary to run a race, as well as crew for Extreme E's operations. Efficiency improvements to the St. Helena include refurbishing the propellers to reduce friction and increase efficiency, as well as anti-fouling paint to streamline the boat through the water, reducing drag and therefore fuel consumption and carbon emissions. Additionally, the ship operates with low sulfur marine diesel (St. Helena, n.d.). However, Extreme E's logistical schedule is very different than F1's. There is much less cargo to contend with, as one container ship can carry all cargo for the entire season, as opposed to the multimodal solution required by F1's cargo volume. Additionally, Extreme E only has 5 race weekends per year, allowing the cargo to be shipped via the slower method of ocean freight (Extreme E, n.d.). Although F1 is not publicly exploring options for reducing carbon emissions with their sea freight, Extreme E could serve as inspiration and a starting point for F1's effort to reduce carbon emissions for their ocean-based logistics.

Despite F1's current efforts, their attempts to minimize carbon emissions in logistics is simply a technological fix to compensate for the inefficiency of the season calendar. According to Weinberg's definition of a technological fix, this appears to be a problem more easily solved through organization rather than technology (Newberry, 2005). At first glance, the calendar seems to be very poorly organized. Although the European leg of the schedule is relatively compact save for a trip to Canada in Round 9, the beginning and end of the schedule is wildly inefficient. The 2023 calendar starts in the Middle East, departs to Australia only to return to the Middle East for the next race. Then, the F1 circus will journey to Miami before returning to Europe for the European leg. After the European leg, the series ventures to Singapore and Japan, then makes a stop in Qatar on its way back to the United States. Races in Mexico and Brazil then follow, only to return to the United States for the penultimate race. Finally, the season ends back in the Middle East in Abu Dhabi. (F1 Schedule 2023 – Official Calendar of Grand Prix Races, n.d.). Additionally, if any of these two races are not back to back, the team will fly back to their European bases, only to fly to the next race the following week. F1 currently claims they will regionalize the calendar into four seasons: one each in the Middle East, Europe, the Americas, and east Asia/Australia. However, this solution has a long-term timeline because many of the current race contracts have to expire and be re-negotiated for different times of the year. Additionally, other considerations need to be considered for regionalization to occur. For example, Abu Dhabi pays a premium to be the final round of the championship each year (Richards, 2022). Miami's race cannot be held in the late summer or fall due to the threat of hurricanes and by virtue of its track being built around a currently operating National Football League (NFL) stadium. Therefore, if F1 wants to solve the root of this problem and not simply apply a technological fix, they need to have a plan in place to factor in these considerations, or source alternative racing sites.

Unfortunately, regionalizing the calendar only reduces emissions, it does not eliminate them. If a true technological fix was applied, regionalization would not be necessary – F1 could apply some of the solutions mentioned in the above analysis in order to achieve carbon neutral travel. If that occurred, the calendar could be as inefficient as possible, and it would still result in less emissions than a perfectly optimized calendar with current transport technology. The effort to regionalize the calendar indicates that F1 is not confident it will meet its net carbon zero sustainability goal. By the time the calendar is regionalized, it would be close to 2030, as the long-term contracts with tracks need to expire. However, if F1 achieves net carbon zero logistics, a regionalized calendar will be unnecessary. This focus, combined with a distinct lack of preparation for net carbon zero air and sea freight, imply that it is very unlikely that F1 will meet its net carbon zero goal for logistics in 2030.

**A Note About Business Travel, Factory Emissions, and Event Operations**

Although business travel, factory emissions, and event operations make up the majority (54.3%) of all F1 carbon emissions, they have not yet been discussed in the analysis (F1 Sustainability Strategy, 2019). This omission is due to the fact that the production of energy for most activities in these three categories - such as emissions from factories, emissions created by operating at race tracks, and lodging for team members – is somewhat out of the control of F1. Perhaps F1 could regulate generator usage during events, but for the rest of these activities, they are drawing power from their local grids. F1 is doing what they can to improve operations, such as using HVO fuel in generators, and using zero-emission vehicles for circuit operations. Additionally, they have set the goal of ensuring all F1 events are "sustainable" by 2025 (F1, 2021). However, the definition of "sustainable" is not given. Because of these factors, it will be difficult for F1 to ensure that its events are net carbon zero, as they do not appear to have a concrete plan in place to meet their 2030 goal. Additionally, factory emissions will be difficult to control, as these factories are located across the globe, accessing different power grids. Like before, F1 appears to have no concrete plan to address this aspect of carbon emissions at the present time. Due to the complexity of ensuring carbon neutrality at these sites across the globe, this issue is outside the scope of the analysis presented in this paper. However, addressing this issue would be a unique opportunity for further research, and one that would have a great impact, as F1 does yet not appear to have a concrete plan to resolve this problem. Finally, other activities contained in these sectors, such as business travel and transporting team personnel, are adequately covered by other methods addressed in this paper, such as alternative fuels.

## Conclusion

In brief, F1 is making substantial, measurable progress towards meeting its goal of becoming net carbon zero in some areas but has no plan to meet the goal in others. The commitment to alternative fuels such as synthetic gasoline and HVO 100 appears successful and viable. However, the lack of planning for the largest contributors to F1's carbon emissions, including air and sea freight, invites skepticism on the viability of F1 achieving their net carbon zero goal by 2030. Additionally, F1 must address social and environmental concerns in their product life cycles before they can claim their goal is met. Although F1 is making progress to reduce carbon emissions, they must urgently take action to tackle areas of carbon emissions with no plan, or else it does not appear they will be net carbon zero in 2030.

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