Determining the effectiveness of HVO fuel in reducing emissions from Formula One's cargo transport in Europe

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OVERVIEW: There are environmental benefits of switching Formula One's fuel for ground transportation to hydrotreated Vegetable oil. This will assist in achieving the goal of Net Zero issued by Fédération Internationale de l'Automobile.

1.Abstract

Since the modern era, the logistics of the FIA Formula One World Championship involved extensive ground transportation, contributing significantly to the sport's overall carbon emissions. To mitigate this circumstance, the Fédération Internationale de l'Automobile (FIA) issued the Net Zero Carbon By 2030 Campaign. Hydrotreated Vegetable Oil (HVO), a renewable diesel that can be directly used in an internal combustion engine (ICE), was adopted by the Mercedes-AMG PETRONAS Formula One Team as a trial in 2022. This study examines the HVO's efficiency in reducing emissions compared to conventional fossil diesel, and therefore analyzes whether it should be widely deployed by other participants in the sport. We first summarize HVO's chemical characteristics and examine its emissions reduction based on existing research in the field. Moreover, two Well-to-Wheel (WTW) models, separated into cargo and non-cargo-based approaches, are used to quantify emission reductions in real-life logistics. The results of the cargo-based method show that HVO achieves an average emission reduction of 83%, with 11.98% of percentage error compared to 90% claimed by Mercedes. These findings support the environmental benefits of switching to HVO, suggesting it as a viable solution to achieve the Net Zero goal.

2. Introduction

In 2024, nine Formula One Grand Prixes were held in Europe. With ten teams participating, up to 300 trucks were involved in transportation including vehicles, components of motorhomes, and spare parts—from race to race. The extensive ground transportation resulted in substantial carbon emissions. Back in 2022, the Mercedes-AMG PETRONAS Formula One Team launched a renewable implementation of sustainable biofuel—Hydrotreated vegetable oil (HVO）, aiming to achieve the goal of net zero in 2030 set by Fédération Internationale del'Automobile (FIA). Whether advanced fuel technology can bring an obvious advantage from an environmental perspective while addressing the energy demand is worth considering. This research project outlines the characteristics of HVO fuel, analyzes its energy efficiency and reduction of emissions, and makes a comparison with traditional diesel. The aim of this study is to determine whether HVO fuel reduces emissions from Formula One's cargo transportation in Europe as effectively as stated by Mercedes. To accomplish this, travel distances and fuel emissions were used in calculations. The ultimate goal is to understand if it is worth having all race teams fully utilize HVO fuel in the future to achieve net zero in 2030.

3.Background

The FIA Formula One World Championship, also known as F1, is one of the most popular sporting events, with an 826.5 million fanbase in 2024 [1]. Alongside the Olympic Games and the FIFA World Cup, it is recognized as one of the world's three major sporting events. To meet growing fan demand and maximize economic returns, the total number of Grand Prix races has expanded to twenty-four, hosted in major cities worldwide—except for Africa.

In 2018, F1's carbon footprint was estimated at 256,551 tons of carbon dioxide equivalent (tCO_2eq) [2]. As the pioneer of technological innovation, the FIA launches the Net Zero Carbon By 2030 Campaign. This first includes eliminating carbon emissions from the internal combustion engine (ICE) in F1 cars. In 2014, new regulations mandated the usage of hybrid engines, evolving into 100% use of sustainable biofuel, and the 2026 regulation requires a halved oil-electricity engine. All initiatives have made significant progress toward sustainability, especially with ICE technology deployed in domestic vehicles, which is expected to reduce global emissions [2].

On the other hand, the route towards Net zero off-track did not progress so smoothly. Europe is the heart of this sport, home to most teams' headquarters and the first-ever Grand Prix was held in the UK. With nine Grand Prix races taking place across Europe within just four months—including a three-week summer break—the demanding schedule places immense pressure on logistics teams, particularly ground transportation. This has raised significant environmental concerns, where logistics account for roughly 45% of total emissions, covering road, air, and marine transport. With only "plans to…ensure F1 moves to ultra-efficient logistics and travel and 100% renewably powered offices, facilities and factories", achieving the goal seems to be less promising [2].

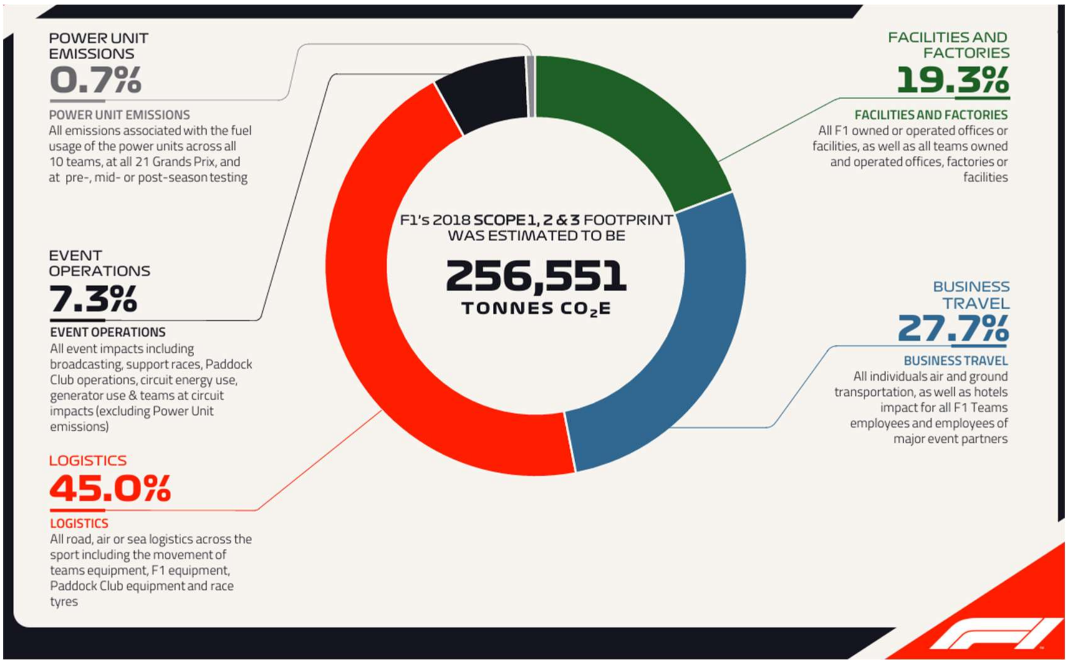

Figure 1. F1's 2018 Scope 1, 2, & 3 footprint estimation composed of logistics, business travel, facilities and factories, event operations, and power unit emissions [2].

The Mercedes-AMG PETRONAS Formula One Team, simplified as Mercedes, acted as an innovator by conducting their first trial using HVO for ground transportation in 2022. The team deployed sixteen Mercedes Actros Gigaspace race trucks to deliver racing cargo for the European series, covering the Belgian, Dutch, and Italian Grand Prix. Mercedes became the first F1 team to utilize this biofuel in their logistics operations, significantly advancing environmental sustainability. They claimed a reduction of 44,091 kg of CO_2 and nearly 90% emission savings [3]. Mercedes also proposed a HVO plan for the 2024 season, where trucks that use HVO fuel will be deployed in all nine European Grand Prix [4].

4. Hydrotreated Vegetable Oil

4.1.1 Introduction and production of HVO

The HVO fuel used by Mercedes is developed and produced by the Finnish company Neste, which is known as Neste My Renewable Diesel [5]. HVO is an alternative biofuel that is more efficient and sustainable than traditional diesel. One of its biggest advantages is that the fuel can be directly applied to a diesel-powered ICE without any modification. Specifically, the HVO100, which contains no butanol mixture like HVOB5 and is derived from 100% used waste oil, is the focus of this research.

HVO is produced by the procedure called hydrotreatment, starting from raw material processing to actual chemical production. In general, vegetable oils, waste oils, and animal fat waste can act as the feedstock for HVO production. The main wanted material within these oils is triglycerides and fatty acids. Take oleic acid, a common fatty acid, as an example. At its pre-processed stage, the oleic acid is unsaturated, meaning it contains a carbon-carbon double bond. Modern industrial production uses hydrogenation to break this double bond by adding hydrogen molecules. This reaction converts oleic acid into stearic acid (simplified as $C_{18}H_{36}O_2$) [6].

$$CH_3-(CH_2)_7-CH=CH-(CH_2)_7-COOH+H_2 \longrightarrow CH_3-(CH_2)_{16}-COOH \quad (1)$$

This not only increases the stability of organic molecules but also results in a high cetane number, which improves combustion efficiency [7].

The composition of HVO is separated into three major reactions: Hydrodeoxygenation, Decarboxylation, and Decarbonylation, which convert vegetation oil (carboxylic acid) into a straight chain alkane between n-C15 and n-C18 (n represents the number of hydrocarbons), or n-paraffins [8]. Specifically, oxygen is removed, forming water, propane, and alkane groups [9].

For hydrodeoxygenation, stearic acid reacts with hydrogen to form octadecane and water. In this reaction, a catalyst such as nickel metal is used. Hydrogen first dissociates on the surface of the catalyst to form hydrogen atoms. These atoms are reduced carboxyl group COOH to aldehyde and then methanol [9].

$$C_{18}H_{36}O_2 + 3H_2 \longrightarrow C_{18}H_{38} + 2H_2O \qquad (2)$$

For decarboxylation, stearic acid forms heptadecane and carbon dioxide, where the carboxyl group is removed under high temperature [9].

$$C_{18}H_{36}O_2 \longrightarrow C_{17}H_{36} + CO_2 \qquad (3)$$

Decarbonylation reaction also requires hydrogen to reduce the -OH groups, forming heptadecane, carbon monoxide, and water [9].

$$C_{18}H_{36}O_2 + H_2 \longrightarrow C_{17}H_{36} + CO + H_2O \qquad (4)$$

4.1.2 Production of HVO-feedstock

As a used product that does not cost any resources to produce, waste oil becomes the most popular feedstock for HVO production. Several types of waste oil can be converted into HVO. Used cooking oil (UCO), also known as “gutter oil” [10], is produced mainly through domestic cooking, restaurant, and other food services, especially for frying. The annual production of UCO is about 190 million metric tons [11]. According to research, UCO production amounts to roughly 20–32% of total edible oil use [12].

Further analysis, according to the data collected in the United States, indicates that each person generates an estimated 4–5 kg of UCO per year [13]. The potential availability of waste oil could reach 2 to 8 million tons annually if similar estimates are applied to the 500 million people who live in the EU27. Based on the equation that, on average, converts 1 kg of UCO into 0.85 kg of biofuel, these numbers suggest that between 1.7 and 6.8 million tons of renewable biofuel could be produced annually in the EU27. UCO is usually sold for between $100 and $300 USD per ton [14][15][16].

On the other hand, tallow, an animal byproduct, is another type of waste oil that can be used for biofuel production. Approximately 2.5 million tons of rendering fats were produced in EU17 in 2005 [17]. An estimated 2.1 million tons of biofuel could be produced [18]. Having a similar price, specifically $200–$550 USD per ton in the market, its life-cycle emissions are higher than those of the base fuel. This is because tallow-based biofuel requires the rendering process, which produce an additional 30% to 50% CO_2 emissions [19]错误!未找到引用源。.

4.2.1 Emission reduction compared to Diesel and biodiesel-combustion stage

To investigate the extent of HVO on emissions reduction to promote sustainability, Valeika et al. conducted an experiment, measuring CO2 and CO reductions using HVO100 and diesel [20]. A CI engine, also known as a diesel motor, was tested at a constant speed of 2000 rpm. The researchers tested the engine under four different load conditions, with braking torque (MB) from 30 Nm to 120 Nm, with 30 Nm intervals. To quantify the experiment, the torque values are converted into brake mean effective pressure (BMEP), which varies from 0.2 MPa, indicating a light load, to 0.8 MPa, showing a high load. In the original experiment, researchers investigated the emission between diesel and butanol blended with different amounts of HVO. However, in this research, the main priority is to investigate how effective HVO100 is on emissions reduction.

Replacing diesel with HVO100 leads to a reduction in carbon dioxide emissions by 3.5 to 6.7%, as shown by the experimental data [Figure 2][20]. This reduction can be explained by the following chemical characteristics. Due to its high hydrogen content (15.45 %m/m), HVO fuel has a high heating value of 44.1 MJ/kg. In comparison, diesel has lower hydrogen content (13.80 %m/m) and heating value (43.1 MJ/kg). Due to this reason, HVO tends to combust more completely, leading to lower amounts of carbon dioxide emissions compared to regular diesel. Also, HVO fuel has a lower elemental carbon to hydrogen ratio compared to diesel, with diesel is 6.24 and 5.46 for HVO, around 12.5% reduction [20]. Similar results are also reported in the study conducted by Bandbafha et al. [22].

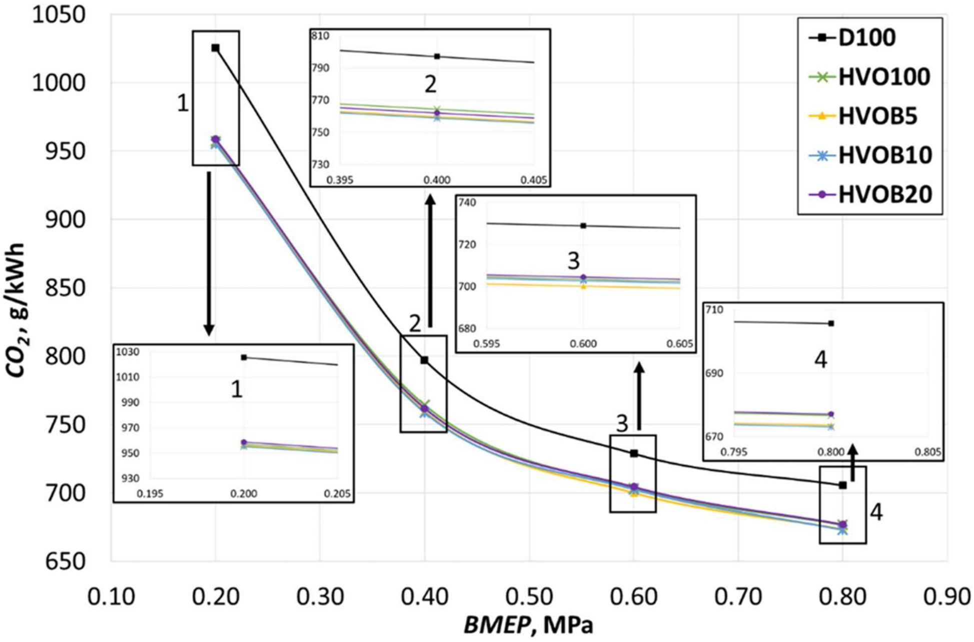

Figure 2. Relationship between brake mean effective pressure (BMEP) (MPa) and carbon dioxide emission (g/kWh) [20]. This study focuses on the comparison between D100 (diesel) and HVO100 (100% HVO). Each box (1-4) represents a different phrase of combustion, from lowest to highest pressure.

The researchers also conducted tests on carbon monoxide emissions using the same method. Under BMEP equal to 0.2MPa, HVO100 usage showed a significant reduction in CO emissions compared to diesel, where the emissions reduced by about 50% [Figure 3]. The reduction decreased to about 6% under 0.6 MPa BMEP, and the value reached almost 0 % at 0.8 MPa BMEP [20].

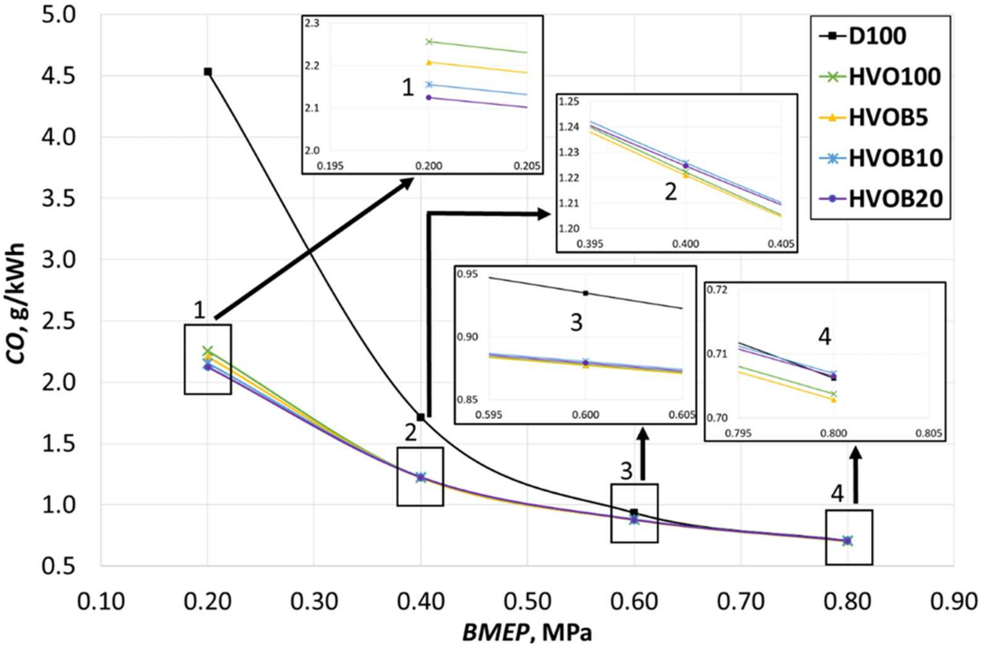

Figure 3. Relationship between brake mean effective pressure (BMEP) (MPa) and carbon monoxide emission (g/kWh) [20]. This study focuses on the comparison between D100 (diesel) and HVO100 (100% HVO). Each box (1-4) represents a different phrase of combustion, from lowest to highest pressure.

The initial reduction of CO production can also be attributed to HVO's lower C/H ratio compared to diesel.

CO is produced through the process:

RH (hydrocarbon molecule) —— R (hydrocarbyl) —— RO2 (alkyl peroxide) —— RCHO (aldehyde) —— RCO (acyl)

Acyl can produce CO through an oxidation reaction. As an intermediate product, carbon monoxide oxidizes into carbon dioxide through the equation.

Under a low C/H ratio, more hydrogen is available to sustain the chain-branching equation; therefore, the amount of hydroxide ions increases. This leads to higher production of carbon dioxide instead of carbon monoxide

$$CO + OH \rightarrow CO_2 + H_2 \quad (5)$$

On the other hand, the exponential decrease in the percentage reduction of CO is possibly caused by more complete combustion in the chamber. High engine load increases the temperature rise, promote the integrity of combustion, and reduce the generation of CO [23].

Moreover, HVO combustion does not generate sulfur oxides (SOx), one of the pollutants that act as indirect greenhouse gases and cause acid rain. Because HVO is produced from waste fats and oils rather than from sulfur-rich fossil feedstocks such as coal or petroleum, its intrinsic sulfur content is virtually zero. Any traces (<5 mg kg^{-1}) detected arise solely from incidental contamination during transport or storage in the existing diesel logistics system. As a result, the exhaust-related problems typically linked to diesel, such as respiratory illnesses, acid deposition, and infrastructure corrosion, are effectively eliminated when HVO is used [24].

4.2.2 Emission reduction compared to Diesel and biodiesel-life cycled assessment

With only a 3.5 to 6.7% reduction compared to diesel, the experiment result is far from the 90% reduction advertised by Neste [20]. This is because the experiment conducted by Valeika et al. does not consider the emission through production.

Therefore, Ajeeb et al. conducted a life cycle assessment (LCA), investigating the total global warming potential (GWP, measured by kgCO2eq per kg HVO) of cooking oil-based HVO [25]. The study is set in Portugal. The experimental methodology follows the ISO 14044 standard and the related instructions for production systems associated with hydrogen. SimaPro software is used for modeling. The process of the LCA is separated into four parts: HVO production, Hydrogen gas production, feedstock treatment, and feedstock transport. Two factors, raw materials used to produce HVO and energy used to produce hydrogen gas for Steam Methane Reforming, contributed to the difference in emissions between different groups. Specifically, either UCO or palm oil is used. For the energy source to produce electricity, the combination of photovoltaic (PV) and wind power (wind), or grid mixed electricity (Grid mix) is used. The former is composed of sustainable energy only; the latter might vary between regions. For example, Portugal’s electricity is composed of 70% of renewable energy, whereas the number dropped to 42% in the USA [26].

Based on RED II and RED III (European Renewable Energy Directives), advanced biofuels must achieve more than 65% of emissions reduction compared to diesel, which produces around 1.18 kgCO2eq/kg diesel [27].

According to the research, HVO produced by UCO with PV/Wind electricity shows the lowest GWP value, with 0.304 kg CO2 eq/kg HVO, achieving 74.23% emission reduction compared to fossil-based diesel [Figure 4]. HVO derived from Palm oil with PV/wind (produced 0.533 kg CO2 eq/kg HVO) decreased the number to 54.83%. Therefore, besides eliminating potential disturbances on the food market, the usage of UCO-originated HVO can further reduce 42.96% of emissions compared to palm-based oil. This is due to the extra emissions produced from palm oil's cultivation and extraction, and other potential environmental pollution, such as soil erosion and salinization, is not presented in emissions.

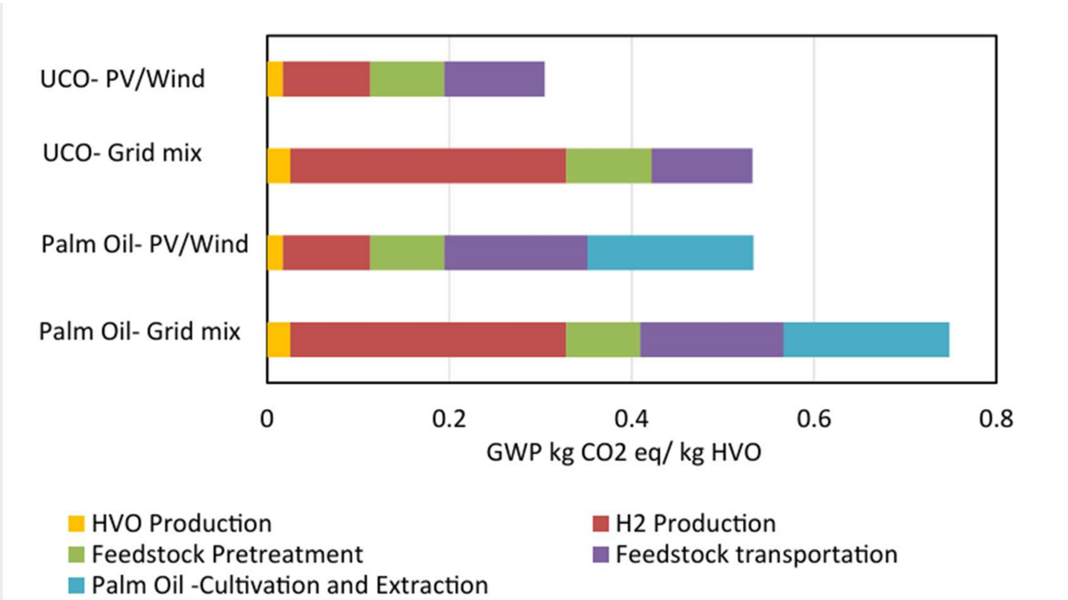

Figure 4. Global warming potential of the total life-cycled assessment value of hydrotreated vegetation oil production for the four scenarios [25].

Within the investigation, HVO production produces the lowest amount of emissions of 0.0175 kg CO2eq/kg HVO, with negligible difference between PV/wind and grid electricity source.

However, emissions caused by hydrogen gas production show a larger gap between renewable and nonrenewable energy. Total GWP using PV/Wind (with the value of 2.34 kg CO2eq/kg H2) was found to be 69% lower than the use of the grid mix electricity supply option (with the value of 7.51 kg CO2eq/ Kg H2).

Switching to renewable energy is more beneficial than replacing palm oil with UCO. However, considering the geographical and economic limitations on using renewable energy, utilizing UCO is a more widely accepted approach.

5. Emission reduction by using HVO compared to Diesel through calculation

5.1 Methodology

To figure out the efficiency of emission reduction for HVO fuel in ground transportation, one way is to adopt the Well-to-Wheel analysis.

The Well-to-Wheel (WTW) emission per unit index, specifically WTW GHG $\frac{gCO2_{eq}}{KM}$ here, an estimated assessment of the amount of greenhouse gas emission, such as carbon dioxide, for a certain type of fuel with certain kilometer distance driving on ground. This can be used to estimate the global warming potential of the fuel for ground transportation.

WTW is calculated by the following equation:

$$CO2_{WTW} = CO2_{WTT} + CO2_{TTW}$$

Through the equation, we can see that WTW is composed of the Well-to-Tank (WTT) index and Tank-to-Wheel (TTW) index. WTT emissions per unit measure the process of producing and transferring the fuel to the vehicle’s fuel tank. Multiple emission sources, such as mining exploitation, production of feedstock like corn, transportation of inputs and products, and production of hydrogen gas, are present in the example of HVO. On the other hand, TTW missions per unit consider the emissions produced during engine combustion, specifically the GHG produced from combustion in ICE. This is influenced by the ICE efficiency, depending on different manufacturers, and the mass of cargo transported.

In the first method, the WTW index for HVO is calculated based on known research and compared with the WTW index for diesel, where the complete data is directly collected from previous research. The mass of cargo in transportation is not considered due to the constraints of mythology.

To simplify the calculation, the TTW index for HVO is ignored. Based on the report of Renewable Energy – Recast to 2030 [28], HVO’s superior high combustion efficiency leads to minimum numbers of emissions, including GHGs other than carbon dioxide, such as NOx and Sox, that does not affect the comparison. The WTT emission per energy consumption index of HVO originated from UCO, addressed by Neste as their sole inputs of HVO production, is collected, with an index of 11.1 $\frac{gCO2_{eq}}{MJ}$ [29].

In comparison to calculating emission production per energy consumption, distance-based approach is more feasible due to the openness and ease of collecting statistics, like the distance between two Grand Prix locations. Therefore, switching unit to $\frac{gCO2_{eq}}{km}$ is needed, utilizing the equation, with factors include fuel consumption ($Q\ L/100km$), fuel density (ρ kg/L), heating value (H MJ/kg), and $CO2_{WTW}(\ gCO2_{eq}/MJ)$.

$$CO2_{WTW}\left(\frac{gCO2_{eq}}{km}\right)=\frac{Q\ (\frac{L}{100km})}{100}\times \rho(\frac{kg}{L})\times H(\frac{MJ}{kg})\times CO2_{WTW}\left(\frac{gCO2_{eq}}{MJ}\right)$$

Fuel consumption per distance is collected from the Mercedes Actros 1845 LS truck, with 25 liters per 100 km on road [30]. As the Mercedes Actros Gigaspace, the series used by Mercedes for logistics transportation, is the upgraded version of Actros series, specifically equipped with an expanded cockpit, however with the same engine, the Actros 1845 LS is expected to have similar combustion efficiency.

For the heating value and density, they are 44.1 MJ/kg and 0.78 kg/L respectively, based on the chemical characteristics of HVO back in section 4.1.

On the other hand, although diesel only has slightly higher WTT index (18.9) than HVO [29], indicating a relatively similar level of emissions in the production stage, its fossil-based characteristics, demonstrating a low combustion efficiency, resulting in high levels of emissions in the consumption phrases, therefore leads to high TTW and WTW for 1056 $\frac{gCO2_{eq}}{KM}$ [31].

Distance between different Formula Grand Prix locations is calculated using Google Maps. The route with the shortest travel time and access to open roads only is selected to simulate the actual route of logistics. The calculation and assumptions are based on the 2024 F1 season calendar, including the overlapping between the 2022 season (which are the only last three races in the European series: Belgium-Netherlands-Italy) [32].

With previous statistics on HVO and diesel's WTW emission per distance, the amount of emission can be calculated by

$$Distance\ \times\ CO2_{WTW}$$

The reduction can therefore be told by

$$Total\ Emission\ Produced_{Diesel} - Total\ Emission\ Produced_{HVO}$$

The second method is utilized on existing emission calculators online to measure the amount of GHG emissions from Diesel fuel, which involves the factor of cargo gross weight that was not covered by the previous method. Inspired by the calculator and research, we imitate the calculation process and calculate the emission of HVO in $\frac{gCO2_{eq}}{tkm}$

The Eco Calculator, developed by CEVA Logistics [33], can calculate the WTW emissions in tCO2eq by inserting cargo gross weight, transport mode (Truck), origin and destination. Mentioned in the calculation rules, “the distance (km) corresponds to the shortest actual route between departure and arrival points”, and “fuel is considered as diesel by default”, matching the route of data selection in the previous method.

Although CEVA Logistics did not show their calculation methods in the rules, another website calculator, Pier2Pier [34], also applied the same method. The $CO2_{WTW}\left(\frac{gCO2_{eq}}{MJ}\right)$ can use the same data in method one, however acquiring unit conversion. The targeted unit can get by multiplying energy efficiency in $\frac{MJ}{tkm}$, where in EU the averaged energy for truck that has a gross vehicle weight more than 20 tons with trailer is 1.6 $\frac{MJ}{tkm}$ [35]. According to The European commission, a three-axle trailer in vehicles forming part of a vehicle combination sector, used by Mercedes, has a maximum authorized vehicle weight of 24 tons [31]. It is assumed that Mercedes reaches the maximum weight for highest transportation efficiency.

$$Weight(ton) \times Distance(Km) \times CO2_{WTW}\left(\frac{gCO2_{eq}}{tkm}\right) = CO2_{WTW}(\ gCO2_{eq})$$

5.2 Results-Method one (Non-cargo weight based)

5.2.1 Calculation of HVO and Diesel emission in $\frac{gCO2_{eq}}{km}$

Inserting values of fuel consumption ($Q\ L/100km$), fuel density (ρ kg/L), heating value (H MJ/kg), and $CO2_{WTW}(\ g\ CO2_{eq}/MJ)$ into the equation, the WTW index for HVO can be calculated:

$$0.25\left(\frac{L}{100km}\right) \times 0.78\left(\frac{kg}{L}\right) \times 44.1\left(\frac{MJ}{kg}\right) \times 11.1\left(\frac{gCO2_{eq}}{MJ}\right)$$
$$95.45\ \frac{gCO2_{eq}}{km}$$

Comparing WTW of HVO (95.45) and diesel (1056), around 90% of emission reduction is shown.

5.2.2 The amount of emission reduction using HVO

The logistical transportation between European Grand Prix races is all ground-transportation based. In which, Mercedes did two different trials on the HVO, with three and ten Grand Prix covered separately. Between Monaco and Spain Grand Prix, Canada Grand Prix was held, however is not European series, so the team did not use ground transportation or HVO. As a result, routes from Monaco to Canada, and from Canada to Spain are not included [Table 1].

Table 1. Distance between European Formula One Grand Prix

Road route	Distance (km)
Autodromo Enzo e Dino Ferrari (Imola) to Circuit de Monaco (Monaco)	503
Circuit de Barcelona (Spain) to Red Bull Ring (Austria)	1584
Red Bull Ring (Austria) to Silverstone circuit (Britain)	1585
Silverstone circuit (Britain) to Hungaroring (Hungary)	1169
Hungaroring (Hungary) to Circuit de Spa-Francorchamps (Belgium)	1383
Circuit de Spa-Francorchamps (Belgium) to Circuit Zandvoort (Netherland)	298
Circuit Zandvoort (Netherland) to Autodromo Nazionale Monza (Italy)	1099

Table 2 shows the total amount of carbon dioxide emission per truck in three different circumstances, which can be calculated with:

$$Distance \times CO2_{WTW}$$

Table 2. Emission reduced using HVO instead of diesel-non-cargo based

Total	route	Diesel-2024 ($CO2_{WTW\,(\,gCO2_{eq})}$)	HVO-2022 ($CO2_{WTW\,(\,gCO2_{eq})}$)	HVO-2024 ($CO2_{WTW\,(\,gCO2_{eq})}$)
	Imola-Monaco	531168	N/A	48011.35
	Spain-Austria	1672704	N/A	151192.80
	Austria-Britain	1673760	N/A	151288.25
	Britain-Hungary	1234464	N/A	111581.05
	Hungary-Belgium	1460448	N/A	132007.35
	Belgium-Netherland	314688	28444.1	28444.1
	Netherland-Italy	1160544	104899.55	104899.55
Total emission		8047776	N/A	727424.45

Total in the last three races		1475232	133343.65	133343.65
Amount reduction to diesel		0	N/A	7957196
Amount reduction in the last three races to diesel		0	1341888.35	1341888.35

With reducing 1341888 $\frac{gCO2_{eq}}{truck}$ of carbon dioxide in the last three races in season 2022, the amount of reduction of 16 trucks in kilograms can be calculated with:

$$\frac{1341888}{1000} \times 16 = 21470.21\ kgCO2$$

Comparing to Mercedes 'claim on reducing 44,091 kg of CO_2 using 16 trucks that used HVO in the last three races of 2022 seasons, a difference of 51.3% is showed [3].

5.3 Results-Method 2 (Cargo weight base)

5.3.1 Calculation of HVO and Diesel emission in $\frac{gCO2_{eq}}{tkm}$

$$11.1\left(\frac{gCO2_{eq}}{MJ}\right) \times 1.6(\frac{MJ}{tkm}) = 17.76(\frac{gCO2_{eq}}{tkm})$$

The Diesel emission in $\frac{gCO2_{eq}}{tkm}$ used by CEVA Logistics can be calculated. For example, the distance between Shanghai Hongqiao international airport and Beijing Capital international airport is 1330.434 km, with 24 tons of cargo, the emission produced is around 3.506 $tCO2_{eq}$.

$$\frac{3.506 \times 1000000}{1330.434 \times 24} = 109.80(\frac{gCO2_{eq}}{tkm})$$

Comparing WTW of HVO (17.76) and diesel (109.80), around 83.83% of emission reduction is shown, lower than the rate shown in method one.

5.3.2 The amount of emission reduction using HVO

Equation in section 5.2 can be used to calculate the amount of emission produced with consideration of cargo weight, shown by table 3.

Table 3. Emission reduced using HVO instead of diesel-cargo based

Total	route	Diesel ($CO2_{WTW}$ ($gCO2_{eq}$))	HVO-2022 ($CO2_{WTW}$ ($gCO2_{eq}$))	HVO-2024 ($CO2_{WTW}$ ($gCO2_{eq}$))
	Imola-Monaco	1325505.6	/	214398.72
	Spain-Austria	4174156.8	/	675164.16
	Austria-Britain	4176792	/	675590.4
	Britain-Hungary	3080548.8	/	498274.56
	Hungary-Belgium	3644481.6	/	589489.92
	Belgium-Netherland	785289.6	127019.52	127019.52
	Netherland-Italy	2896084.8	468437.76	468437.76
Total emission		20082859.2	/	3248375.04
Total in the last three races		3681374.4	595457.28	595457.28
Amount reduction to diesel		0	/	16834484.2
Amount reduction to diesel in the last three races		0	3085917.1	3085917.1

With reducing $3085917.1\frac{gCO2_{eq}}{truck}$ of carbon dioxide in the last three races in season 2022, the amount of reduction of 16 trucks in kilograms can be calculated by

$$\frac{3085917.1}{1000} \times 16 = 49374.67\ kgCO2$$

Comparing to Mercedes 'claim on reducing 44,091 kg of CO_2 using 16 trucks that used HVO in the last three races of 2022 seasons, the inaccuracy has decreased to 11.98% [3].

6. Discussion and Conclusion

To conclude, compared to non-cargo based method with an inaccuracy of 50%, cargo weight based with an inaccuracy of around 12% is a better model to estimate the emissions reduction by replacing diesel with HVO.

However, both methods do not perfectly match the data released by Mercedes (as well as Neste) on the amount of reduction. Therefore, several reasons are proposed to explain these disparities.

Firstly, the measurements of Mercedes do match the theoretical data of 90% reduction, indicating some potential uncertainties. With the same distance travel between each Grand Prix location, a percentage reduction that matches the theoretical 90%, just like in method one, should result in a similar amount of GHG emissions. However, the difference is over 50%.

This leads to the next conjecture, where Mercedes might not necessarily choose the optimum route suggested by Google Maps, or decide to return to their Headquarters and factories for spare parts, as they are located in the UK, close to most of the locations in the European series. This means that Mercedes' truck might have travelled longer distances than we estimated, leading to higher amounts of reduction in emissions production.

For method one, the statistics collected from Mottschall et al. might create inaccuracies. Possible reasons include: 1) The Engine type might be different between the diesel engine and HVO Actros engine, as Mottschall et.al. did not indicate the version of the experimental truck. The difference in combustion efficiency influences the TTW index; or 2) The average fuel consumption might not indicate real-life circumstances, for example, evasive braking due to traffic lights, jams, and driving habits (ie, Reckless or over-prudent). This would also influence the TTW index, leading to inaccuracy.

In method two, the WTW assessment was used instead of the life-cycle assessment. The decision was taken due to the following reasons. A complete LCA requires more extensive data collection (lack of statistics), complex calculations, and differences to make a comparison between two types of fuel. The ease brought by WTW assessment also comes with drawbacks, as it does not account for other environmental factors other than GHG emissions. For example, the use of water for cooling includes water pollution. The assessment might therefore underestimate the negative effect brought by HVO, leading to widespread environmental pollution.

Recently, the Environmental, Social and Governance (ESG) report released by FIA in July 2025 has shown promising progress towards the target of Net Zero in 2030. The total emission produced by F1 at the end of season 2024 is 168720 tons CO2eq, achieving a 26% reduction compared to 228793 tons CO2eq at the end of season 2018. Utilization of HVO is indeed effective, where the data shows an average reduction of 83% of emissions in ground transportation [36].

Worth noting is that F1 has also targeted multiple other emission sources related to the sport that are not discussed in this research. Specifically, Sustainable Aviation Fuel (SAF) has been used, reducing emissions by more than 8,000 tCO_2e in air logistics [36]; racing with Forest Stewardship Council (FSC)-certified tyres provided by Pirelli [37]; and minimizing additional transportation distances through improved calendar arrangements. Therefore, approaching and ultimately achieving the Net Zero goal does not—and will not—depend solely on biofuel innovation, but also on a comprehensive strategy that integrates logistical efficiency, sustainable materials, and logical scheduling.

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