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Analyzing and Implementing Sustainable Aviation Fuel Solutions

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Abstract: This is a study of the impact of air transportation on the environment through emissions of CO2 and other pollutants, which are the causes of climate change. In Indonesia, transportation constitutes 27% of greenhouse gas emissions, especially in areas like Jakarta. This study purpose is to give a solution to deal with this situation by changing the fuel from conventional jet fuel to Sustainable Aviation Fuel (SAF) and to open opportunities in Indonesia by appealing to eco-conscious consumers and fostering technological innovation. This study mainly based on qualitative research with interviewing companies that are related to this study and research. The results of this study show that SAF is the key to saving climate change caused by air transportation emissions and many other benefits. SAF offers similar chemical ingredients to traditional jet fuel but with lower greenhouse gas emissions.
Keywords: *Sustainable aviation fuel, Climate change, Reduce emission, Air pollutions, Aviation fuel effect, Indonesia environment, Environment.*

1. Introduction

Transportation involves the movement of people, animals, and goods from one location to another, making it a vital element of the modern world. Air transportation is important for the international and global economies because of its ability to travel long distances quickly, that takes days or weeks to travel by land or sea. This type of transportation is important in promoting international communication because it allows people to travel between countries for recreational, business, and tourism purposes. It is also important for emergency services to be able to respond quickly in the event of a medical emergency or natural disaster when time is the most important thing. In addition, air travel is important for social communication. People can understand different cultures, thus encouraging international understanding and cooperation. The tourism sector, which relies heavily on-air travel, unites various community groups and improves the local economy. The most popular way today is air travel because people want to travel quickly and safely, especially for a short period of time. Our country, Indonesia has a company that produces SAF, Pertamina's SAF is designed to be environmentally friendly by incorporating palm oil components in its formulation, which helps to reduce aircraft exhaust emissions. These standards consist of lowering internet lifestyles cycle greenhouse emissions via way of means of as a minimum 10% in comparison to standard fuels, warding off manufacturing from biomass in high-carbon inventory areas, and making sure nearby water, soil, air quality, and meals safety are preserved (Teoh et al., 2022).

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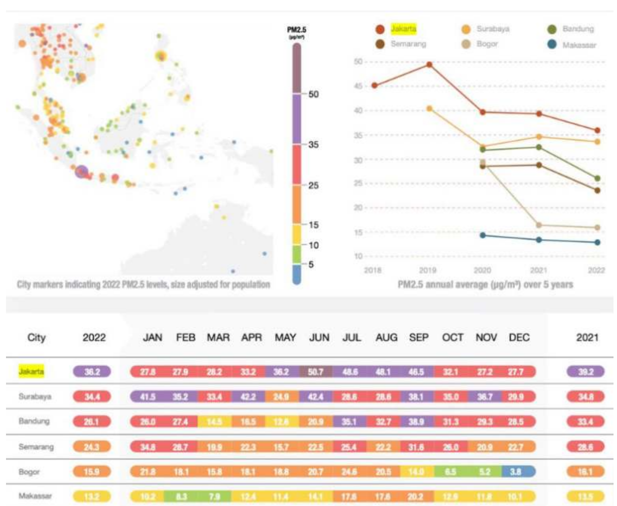
Since PT Pertamina (Persero) has developing SAF, Garuda Indonesia is the first airlines in Indonesia that have been using it for trial, And according to (Sekartadji et al., 2024) Garuda Indonesia used PT Pertamina (Persero) and Bandung Institute of Technology (ITB) collaboration, This collaboration has resulted in the successful production of a mixed biofuel called bioavtur, which contains 2.4% palm oil. The new 'red and white' catalyst used in this research was developed by ITB and represents major advances in biotechnology. On September 10, 2021, an important step in this process was achieved due to the success of the test flight. The one that was tested was a CN 235-220 FTB aircraft owned by PT Dirgantara Indonesia. This grand event took place at Hangar 2 of PT Garuda Maintenance Facility Aero Asia Tbk (GMF) in Tangerang and featured the use of new biocomposites. After this initial success, additional testing was carried out to evaluate the performance of biofuels in commercial aviation environments. On October 27, 2023, the biofuel on the Boeing 737-800 aircraft underwent detailed testing. This test flight covers the route from Soekarno-Hatta Airport in Jakarta to Adi Sumarmo Airport in Surakarta. The results of this commercial flight test are expected to provide important insight into the efficiency and effectiveness of biofuels for widespread use in the aviation industry as mentioned in (Cabrera & Melo de Sousa, 2022) Research. Airplanes have a significant impact on the environment due to emissions from aircraft fuel making the reason to swith to SAF. Global warming and excessive consumption of fossil fuels are major threats to global health. It’s essential to recognize that aviation emissions include both CO2 and non-CO2 components, and their impact on climate change is expected to rise due to increased air travel demand and limited decarbonization opportunities according to (Teoh et al., 2022) Research. CO2 is arguably the most well-known greenhouse gas it has contribute about 2.5% of global CO2 emissions due to fossil fuel combustion and more. This represents roughly 12% of the total emissions from the transportation sector based on (Cordina, 2002) Research.



City	2022	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2021
Jakarta	36.2	27.8	27.9	28.2	33.2	36.2	50.7	48.6	48.1	46.5	32.1	27.2	27.7	39.2
Surabaya	34.4	41.5	35.2	33.4	42.2	24.9	42.4	28.6	28.6	38.1	35.0	36.7	29.9	34.8
Bandung	26.1	26.0	27.4	14.5	16.5	12.6	20.9	35.1	32.7	38.9	31.3	29.3	28.5	33.4
Semarang	24.3	34.8	28.7	19.9	22.3	15.7	22.5	25.4	22.2	31.6	26.0	20.9	22.7	28.6
Bogor	15.9	21.8	18.1	15.8	18.1	18.8	20.7	24.6	20.5	14.0	6.5	5.2	3.8	16.1
Makassar	13.2	10.2	8.3	7.9	12.4	11.4	14.1	17.6	17.6	20.2	12.9	11.8	10.1	13.5

As seen in the figure 1 the global air pollution report for 2022 has been released by IQAir, a technology company based in Switzerland. This time, the report contains PM 2.5 air quality data from 7,323 cities in 131 countries, regions, and territories. The data used in this report was collected from more than 30,000 official air quality monitoring stations and low-cost air quality sensors operated by government agencies, research, non-profit non-governmental organisations, universities and educational facilities, private companies, and citizens around the world. The PM2.5 data in this report is measured in micrograms per cubic meter (μg/m3) and combines the 2021 World Health Organization (WHO) air quality guidelines and temporary targets as a basis for data visualisation and risk communication. This is all done with the aim of

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helping in further exploring the data and better understanding the risks. Data from IQAir states that besides Jakarta, there are several big cities in Indonesia that have high pollution levels. These cities include Surabaya (34. 4 µgram/m3), Bandung (26. 1 µgram/m3), and Semarang (24. 3 µgram/m3). Listening to the same report, poor air quality plays a role in more than six million deaths every year in all parts of the world.
Over 50% of indonesia population now resides in urban areas, and the rate of urban population growth in Indonesia is among the highest in Asia. Coastal groups and people reliant on agriculture face expanded vulnerability because of droughts, growing sea levels, floods, and landslides. In Jakarta, air pollution is the most concerning thing. The transportation sector contributes 27% of Indonesia's greenhouse gas emissions, worsening air quality problems based on (Haryanto, 2018) Research. Regarding in this research we have found the problem are (1) Impact of air transportation fuel to the environment (2) Lack of public understanding regarding the materials and origins of SAF, which can hinder its acceptance and adoption (3) and one of the significant challenges facing SAF industry today is the high cost of sustainable aviation fuel (SAF), that is markedly more expensive than traditional jet fuel; this price disparity not only poses a financial hurdle for airlines that are eager to transition to sustainable fuel options but also complicates their efforts to reduce carbon emissions and meet sustainability goals (4) Additionaly, it is difficult for SAF industry to gain public support for the transition to more sustainable fuels.

2. Research Method

Researchers often have a point of view, whether formal or not, that affects the implementation of research. The key assessment in qualitative research is whether the theory underlies research (deductive) or is the result of research (inductive), or whether the natural science research model is suitable for studying the social world (epistemology, and the social world of something outside it). researchers or something that researchers do (ontology). according to (Rhodes & Coomber, 2010) Research. Rich descriptions of phenomena are made possible with the use of qualitative approaches. They improve knowledge of both the events themselves and their context. Using these techniques helps to improve peripheral vision, which is particularly crucial in the early phases of investigation. Clarifying the values, terminology, and meanings attached to individuals who perform dissimilar roles in organisations and communities is another crucial function of qualitative research. Instead of forcing people to fit into labels and classifications that others have imposed on them, they enable people to speak in their own voices. Qualitative researchers frequently discover that they are providing a voice, especially to individuals who are seldom heard otherwise, including patients or employees who are located well down the chain of command (Carlier et al., 2003). In qualitative research, findings and data can be determined to be valid if there is no inconsistency between what the researcher said and what was researched. The validity of the data was measured using the triangulation method. Triangulation is a technique in data collection to improve data findings and interpretation (Luthfiyah, 2017).

In qualitative research, researchers have a choice to do the research from interviewing employee that refers to the paper they make. In this study, we have conducted deep interviews with Directorate General of Civil Aviation, Pertamina SAF, also Management of Garuda Indonesia Operation and Garuda Maintenance facilities on their free time at afternoon and the interviews take about one and a half hours per interviewers. The question that we have been asked to Directorate General of Civil Aviation is about Garuda Indonesia's authorisation to experiment with the use of sustainable aviation fuels at that time and for Pertamina we have been asked about their sustainable aviation fuel materials that they used on Garuda Indonesia last year also

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for Garuda Indonesia Airlines is more about Sustainable Aviation Fuel that they have been try on their aircraft last year, we got a lot of Sustainable Aviation Fuel point of views from Garuda Indonesia including their bittersweet and their reasons for using sustainable jet fuel. The advantages from Qualitative Research Method are that we can explore more and ask our own question and discuss as we doing the research.

3. Result and Discussions

According to Garuda Indonesia from our interview where we questioning about their experience, the reasons why Garuda Indonesia uses SAF is because Garuda Indonesia and Pertamina want to jointly realise their commitment to actively contribute to the carbon emission reduction program by continuing to develop environmentally friendly fuel for commercial aircraft. That's why Garuda Indonesia plans to use SAF, after previously Garuda Indonesia in 2023 successfully passed its first test flight. The first test flight has been carried out in the hangar of 4 Garuda Maintenance Facility Aeroasia, Soekarno Hatta international airport area, Tangerang, Banten.SAF was tested with ground round and flight test stages on Boeing 737 - 800 NG commercial aircraft with registration number PK - GFX. From the results of the flight test, the research team of PT. LAPI ITB delivered a positive result that SAF with Bio Avtur J2.4 type on Boeing 737 - 800 aircraft type shows the aircraft's response is good and under control. The use of SAF itself does not affect the engine/engine performance of the aircraft which means that it is safe and works like aircraft fuel in general. With the definition and main aspects of SAF that are explained thoroughly, Garuda Indonesia can explore environmental, economic and social benefits SAF can reduce greenhouse gas emissions (GMK), life cycle. The primary advantage of Sustainable Aviation Fuel (SAF) is its potential to significantly reduce greenhouse gas (GHG) emissions. Depending on the raw materials and technology used in its production, SAF can also offer additional environmental benefits and contribute to the overall health of the planet. Beyond lowering CO2 emissions, SAF can improve air and water quality by reducing the emissions of sulfur oxides (SOx) and nitrogen oxides (NOx), which are major pollutants harmful to human health and ecosystems. Additionally, cultivating biomass crops for SAF production can support the economic wellbeing of rural agricultural communities by providing economic opportunities for farmers. For Garuda Indonesia, SAF not only has environmental benefits but also enhances aircraft performance. SAF contains fewer aromatic compounds, which leads to more efficient combustion in aircraft engines. This efficiency improves overall aircraft performance and reduces local emissions of harmful substances during takeoff and landing at airports.

Based on our research, **we have analyze the impact of air transportation fuel to the environment especially the air condition in Jakarta is not as good as it supposedly as air transportation is the busiest among all transport it makes the emissions of it a big impact to the environment, the solution is** (1) To change the regular jet fuel to Sustainable Aviation Fuel (SAF). SAF can be called as renewable jet fuel, or bio-jet fuel, all of which are identical. 'Biofuel' it means fuel that comes from a biological source such as plant or animals. In Indonesia, several companies are involved in supporting Sustainable Aviation Fuel (SAF) initiatives. Among these, Pertamina is actively engaged in SAF development as part of its broader efforts to transition to cleaner energy, particularly within the aviation sector. This initiative aligns with the country’s goal of achieving net zero emissions (NZE) by 2060. Biofuels or SAF made their debut in aviation in 2008 when Virgin Atlantic Airlines conducted a pioneering test by blending 20% biofuels with traditional jet fuel. This marked a significant milestone in the pursuit of more sustainable aviation practices. Following Virgin Atlantic's lead, several other airlines, including Air New Zealand and KLM, have also embarked on their own

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trials using biofuels. These efforts are part of a broader initiative to explore alternative energy sources and reduce the environmental impact of air travel. In 2017, Hainan Airlines took a notable step forward by utilizing biofuels derived from used cooking oil, mixed with conventional jet fuel, for a flight from Beijing to the United States. This innovative approach not only demonstrates the practical application of recycled materials but also highlights the potential for biofuels to contribute to more sustainable aviation practices (Sena et al., 2021).

We have found the solution of public lack of understanding in SAF materials and origins, (2) To give public transparency and knowledge. The quality of biofuels can vary significantly based on the production process and the source of the raw materials. Research has shown that biofuels typically contain oxygen, which results in a lower heat value and energy density compared to conventional jet fuel. To address this, technology is employed to refine biomass to meet aviation standards. Biofuels are not intended to fully replace traditional jet fuel; instead, they are initially used in blends of 10 to 20%. In these tests, biotechnology has not been modified due to its high cost and limited effectiveness. Comprehensive testing, particularly heat testing, is crucial to ensure that the required emission reductions are achieved. However, further research is needed to optimize biofuels for efficient combustion, scalable production, and cost-effectiveness in aviation (Sena et al., 2021). The production of Sustainable Aviation Fuel (SAF) utilizes three main categories of conversion technologies: oleochemical, biochemical, and thermochemical. Oleochemical conversion involves the processing of various fatty acids through physicochemical methods to produce SAF from fats and oils. Biochemical conversion transforms carbohydrate-rich feedstocks into intermediate products with the help of microorganisms, leveraging biological processes to create fuel. Meanwhile, thermochemical conversion breaks down the macromolecules of solid biomass using high temperatures and a lack of oxygen, employing thermal techniques to produce SAF. Each of these technologies provides a unique approach to SAF production, contributing to the development of sustainable fuel options for aviation (Martinez-Valencia, Lina, Peterson, S., Brandt, K., King, A. B., Garcia-Perez, M., & Wolcott, 2022). According to (Rony et al., 2023) Aviation fuel is renowned for its high energy density, which is essential for the efficient performance and successful operation of aircraft. This characteristic ensures that the fuel can provide the necessary power and endurance required for flight. Given this critical requirement, any proposed biofuel for aviation must adhere to stringent international standards to be considered viable. Specifically, the biofuel must exhibit thermal stability, meaning it should maintain its properties and performance even under varying temperatures and operational conditions. Additionally, it must possess acceptable cold flow qualities, which are crucial for preventing the fuel from becoming too viscous or solidifying at low temperatures. A low freezing point is also essential to ensure that the fuel remains liquid and functional during high-altitude flights where temperatures can be extremely low. Moreover, for bio-aviation fuel to be adopted widely, it must be fully interchangeable with the conventional aviation fuels currently in use. This means that it should be compatible with existing aircraft engines and infrastructure without requiring modifications or causing operational disruptions. The ability to seamlessly integrate biofuels into the existing fuel supply chain is crucial for their successful implementation and acceptance in the aviation industry.

According to (Yusaf et al., 2022) Reseach, There are two major producers of Sustainable Aviation Fuel (SAF): World Energy and Neste. World Energy initiated its SAF production in 2016 at its facility in Paramount, California. Initially serving United Airlines, the company later expanded its partnerships to include KLM. Currently, Neste stands as the largest global producer of SAF and renewable diesel. The company utilizes a multi-product pipeline to transport SAF from its refinery in Rotterdam, Netherlands, to San Francisco International

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Airport. Neste MY Renewable Jet Fuel™, one of their SAF brands, is produced from renewable waste and by-products, such as used cooking oil and animal fats. Neste manufactures these renewable fuels in Finland, the Netherlands, and Singapore. The company is also set to boost its annual production capacity from 3.2 to 4.5 million tons by the first quarter of 2023, with Singapore alone contributing 1.3 million tons. The facilities in Rotterdam and Singapore are recognized as some of the largest and most efficient renewable fuel plants globally. In Indonesia we have Pertamina SAF as the producer that have been try on Garuda Indonesia last year the improvement of SAF is one of Pertamina's efforts towards energy move and the accomplishment of net-zero goals in 2060. Pertamina's newest biofuel, bioavtur, is a blend of palm oil and aviation fuel, specifically designed for aircraft. The company is working on incorporating Refined Bleached Deodorized Palm Oil (RBDPO) into this aviation fuel, this will diminish exhaust emissions from airplanes. As a leading energy transmission company, Pertamina is dedicated to supporting the zero-emission target for 2060. The company achieves this by investing in projects that directly contribute to the attainment of the Sustainable Development Goals (SDGs). All of these exercises are in line with the implementation of environmental, social, and governance (ESG) regulations in all commerce and mechanical regions of Pertamina (Dwi Jofanka & Bagus Ketut Bayangkara, 2024)

SAF is also have a high cost, and we have found the strategy to reduce the high cost of SAF, (3) By minimize the expand and managing the risks of growing SAF industry, incentives play a crucial part because of high production expenses. Support for emerging industries is one key incentive. Dr. Reed highlighted that the Inflation Reduction Act of 2022, driven by political action in Washington, DC, includes programs and packages to aid SAF and renewable diesel production, aiming to address market demands over the next 5 to 10 years. The Department of Energy (DOE) is actively advancing technology for next-generation SAF by increasing feedstock sources and production pathways, which will help lower SAF costs and the prediction of SAF increasing by 5 years ahead. Scaling up these technologies is crucial for turning research into commercially viable products, and DOE's funding provides the necessary cost-sharing to encourage the industry to invest in large-scale facilities and SAF production demonstrations according to (Fu et al., 2023) Research.

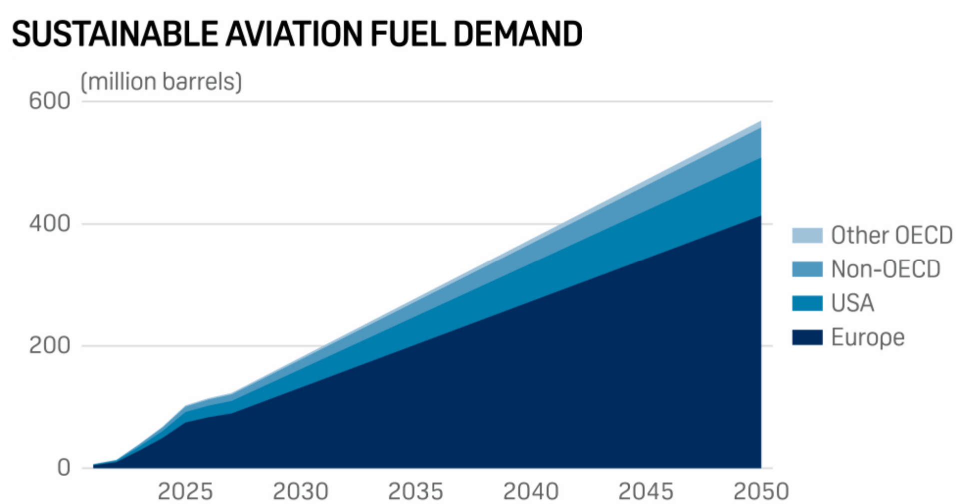

Figure 1 Long-term demand for SAF could run into supply constraints

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From our findings, as shown in figure More and more countries are proposing or adopting long-term sustainable aviation fuel blend (SAF) targets. S&P Global Commodity Insights estimates that SAF demand can reach 5.8% of global aviation fuel demand by 2050, especially in Europe and the United States. To achieve this goal, 17.5 billion gallons of various sustainable fuels are required per year. sustainable aviation fuels in the future will gain the market it means our country should take this opportunity and implementing the solutions that has been explained above to successfully enter the market. The growth of demand creates many opportunities for companies involved in the production and distribution of SAFs. By continuing to build a biogas power plant, Pertamina is in the right position to take advantage of this emerging market. Pertamina's current strategy is very in line with the increasing demand for SAF and is an effective way for companies to enter the SAF business. Since the SAF market is still relatively new, there are many opportunities for newcomers to make a significant impact. In addition, the current very strong SAF price makes this market attractive as it mention on (Gunawan & Aprianingsih, 2023) Research.

From our findings to successfully enter the SAF market and gain public support, (4) Pertamina must develop a planned marketing strategy. The focus of this strategy is to make Pertamina a major player in the SAF industry by utilizing biofuel capabilities to meet the increasing demand for environmentally friendly jet fuel. The need for sustainable jet fuel will increase as more and more domestic and international airlines integrate the SAF into their operations to achieve those fuel reduction goals. Airlines supposed to using SAF more often to meet environmental rules and sustainability promises. This leads to a strong and growing SAF market, requiring Pertamina to quickly seize its portion of this chance. Creating a thorough marketing plan is essential for Pertamina to successfully penetrate the SAF market. This plan should include market research to understand demand patterns, competitive position and customer needs. In addition, Pertamina must also focus on building a strong relationship with airlines. By adapting to the changing needs of the aviation industry and demonstrating the benefits of SAF to the environment, Pertamina can position itself as a leading supplier of sustainable jet fuel and lead the emerging market. This plan should include market research to understand demand patterns, competitive position and customer needs. In addition, Pertamina must also focus on building a strong relationship with airlines. By adapting to the changing needs of the aviation industry and demonstrating SAF's benefits to the environment, Pertamina can position itself as a leading supplier of sustainable jet fuel and lead a growing market based on (Gunawan & Aprianingsih, 2023) Research.

Current status of Sustainable Aviation Fuel (SAF) initiatives in Indonesia

According to (Nugroho et al., 2024) Research, In 2060 or earlier Indonesia is determined to improve emissions to reach Net Zero Emission. This is in line with the President's speech at the 21st Conference of the Parties (COP) United Nations Framework Convention on Climate Change (UNFCCC) in Paris (November-December 2015), where Indonesia aims to reduce greenhouse gas emissions by 29%. It is strengthened. GHG) (has its own ability) or a 41% decrease (with international assistance) by 2030. The development of SAF in Indonesia is led by the Ministry of Transportation, the Ministry of Energy and Mineral Resources, Pertamina and the Bandung Institute of Technology, this is done through the issuance of the Law of the Ministry of Energy and Mineral Resources No. in 2020 and 5% in 2025.

Based on our findings variety of feedstocks, such as palm oil, coconut, microalgae, and others, can be used to produce Sustainable Aviation Fuel (SAF), palm oil is currently the most practical and widely available option in Indonesia. The development of bio-jet fuel in Indonesia is still

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in the pilot phase, with Garuda Indonesia, spearheading these efforts. Pertamina, the state-owned oil company, is also working on demonstrating the feasibility of biofuels for routine flights. Since January 2021, Indonesia has participated in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) pilot phase, a program by the International Civil Aviation Organization (ICAO) aimed at offsetting carbon emissions from international flights beyond a set baseline. Additionally, Indonesia has launched a domestic carbon market initiative known as the Carbon Archive Scheme (National Carbon Scheme), which involves the commercial aviation sector in greenhouse gas reduction efforts. However, participation in this program is voluntary, meaning there are no legal penalties for entities that do not report or verify their emissions. according to (Atmowidjojo et al., 2021) Research.

4. Conclusion

Based on the results of our research it is shown that the transportation sector, especially aviation, plays a crucial role in the modern world but faces significant environmental challenges, particularly concerning carbon emissions and global warming. The aviation industry contributes notably to these issues, accounting for a substantial part of global CO2 emissions and other climate impacts. To address these environmental concerns, transitioning to Sustainable Aviation Fuel (SAF) offers a promising solution. The adoption of SAF, while still facing challenges such as high production costs, is being solved through supportive policies and incentives that aim to scale up production and reduce expenses. And solution of public lack of understanding in SAF materials and origins is by give public transparency and knowledge, also to successfully enter the SAF market and gain public support, Pertamina must develop a planned marketing strategy and gain a good relationship with airlines.

The demand of SAF is getting higher by 2030 tp 2050 it means our country should take this opportunity by involve in the production and distribution of SAF. By aligning its strategies with the growing demand for sustainable aviation solutions, Pertamina has the potential to become a leading supplier in the Indonesia SAF market, contributing significantly to global efforts to reduce aviation's environmental impact and achieve sustainability goals.

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