

Assessment of the Value of Large-Scale Use of Sustainable Aviation Fuels for Global Flights in 2050

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Abstract. By analyzing the projected data for the year 2050, it will be determined whether it is worthwhile to fully replace regular jet fuel with sustainable jet fuel in the future, based on the cost and efficiency in reducing carbon emissions. Although SAF still has many drawbacks at this stage (e.g., relatively low conversion efficiency, high cost, etc.), its reduction in carbon emissions should not be overlooked, and thus the full-scale use of SAF is still a topic for discussion. Therefore, this paper focuses on the impacts and harms of carbon emissions as well as the advantages and disadvantages of SAFs, while comparing and estimating the situation at this stage using various data projections for 2050 provided by a number of organizations and companies. The data points out that the biggest problems with SAFs are cost and trust. The real reason for the high cost is the loss of resources in the conversion of raw materials to kerosene due to the lack of technology, which in turn requires the consumption of more materials to make up for this shortcoming, and the issue of trust in SAFs arises from this. However, the core of the problem is quite simple. If it is just a matter of technology, then given the rapid advancement of technology, one day we will be able to solve it. Therefore, the full use of SAF is necessary because it will significantly reduce carbon emissions, pollution, and global warming. It will also contribute greatly to the environmental protection of mankind.

Keywords: carbon emission reduction, sustainable aviation fuel, greenhouse gas.

1. Introduction

Carbon emissions are a hot topic today, and many countries have declared net-zero carbon emissions by 2050. Why is carbon emission so important? Because carbon emissions are very harmful and it directly affects global warming, which directly affects human survival. There are 2 per cent of carbon emissions are generated by aviation, and utilizing new fuels is one strategy the business is using to lessen its impact on the environment. These alternative fuels come from a variety of sources, often referred to as sustainable aviation fuels or alternative fuels, most of which can be used in existing aircraft. If the aviation industry is to meet the net-zero emissions objective by 2050, it will have to overcome a number of significant challenges in the coming decades. Airlines are expected to carry 10 billion people by that time, more than doubling the 4 billion passengers they handled before the 2019 pandemic, as defined by the International Air Transport Association (IATA). The aviation industry is heavily reliant on the development of sustainable aviation fuels, with IATA projecting that such fuels will provide 80 percent of the airline industry's emissions reductions by 2050, and that the global market for 106 billion gallons (21 billion gallons domestically) of commercial jet fuel will grow to more than 230 billion gallons. Cost-effective, environmentally friendly aviation fuels (SAF) are acknowledged as a crucial element in separating carbon growth from economic expansion [1].

2. The Harm of Carbon Emission

With the progress of society, more and more high-tech products bring convenience to our lives while environmental protection issues have also entered the public's view. Among them, the issue of greenhouse gas emissions has attracted much attention. Greenhouse gases, also known as carbon emissions, have many effects on the earth's ecological environment. Since the Industrial Revolution, both the global average temperature and the average surface temperature have risen significantly, and the trend of temperature increase is getting faster and faster, leading to the record-breaking melting

of the North and South Polar ice caps in recent years, the accelerated rise of the global sea level, and the frequent occurrence of extreme weather and other serious consequences. The increase in greenhouse gas emissions is the main cause of this phenomenon, which has now become the consensus of the scientific community. Between the Industrial Revolution and 1950, industrialized countries were responsible for generating 95% of the world's total carbon dioxide emissions, and 77% of those emissions between 1950 and 2000. China was responsible for 8% of the world's carbon dioxide emissions over the 100 years between 1904 and 2004. The data suggests an overall upward trend in global carbon emissions from 1970 onwards as shown in Fig. 1. Eventually, carbon emissions will peak in 2019. However, because of the new coronavirus in 2020, people will be less inclined to go out and be in contact with people, which in turn will reduce their use of transportation. This explains the drop in total carbon emissions in 2020. In addition, after 2020, the total carbon emissions show a rebound trend. These rebounds among them are visible in the majority of industries and major emitting countries. Three segments, which together account for 89% (1.4 Mt CO₂) of the total global rebound, increase their emissions in 2021 by 5.0%, 2.6% and 8.9%, respectively. However, the largest rebound is mainly contributed by the aviation component, with domestic and international flights increasing by 25.8 per cent (65 MtCO₂) and 18.1 per cent (50 MtCO₂), respectively [2].

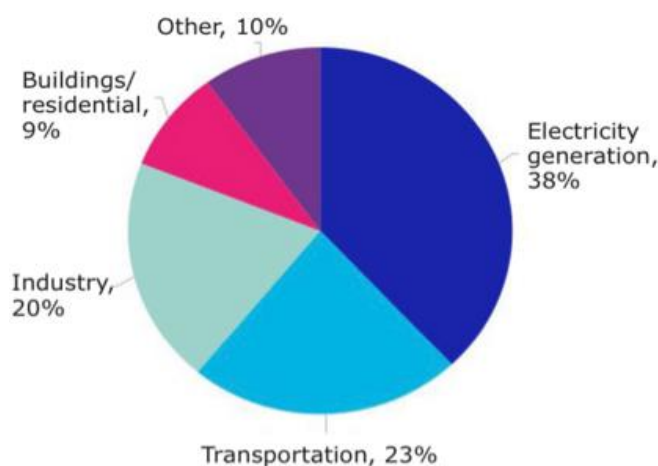


Figure 1. global CO₂ emissions from fossil fuels, broken down by sector [3]

3. Total carbon emissions in recent years and future targets

China is responsible for 10.2 billion tonnes, or 27.9%, of global carbon emissions, according to the International Energy Agency. Most of the carbon emissions come from the transport sector. Of this, carbon emissions from the transport sector account for 9.7% of the country's total emissions, and the volume of carbon emissions from civil aviation accounts for about 1% of the country's total emissions, while for transport emissions, the number is about 11%.

The necessity of cutting carbon emissions from the aviation sector is an important part of global economic activity and a "big carbon emitter", is becoming increasingly apparent. Approximately 2.5% of global carbon emissions and 3% of all oil products consumed worldwide are attributable to the aviation sector.¹ However, compared to buses, trains, and passenger vehicles, which have already consolidated measures for the use of biofuels, aircraft operations have an average energy intensity of 1.8 MJ per passenger km totally supplied by fossil fuels. Ambitious objectives were established for the aviation sector for the coming years, including increasing energy efficiency, achieving carbon-neutral growth from 2020, and decrease carbon emissions to half by 2050 [4]. Compared to International Civil Aviation Organization (ICAO) projections, global carbon emissions from civil aviation increased between 2013 and 2019 [5]. By 2050, aviation will contribute 25% of the world's carbon emissions. Prior to 2019, transport will overtake industrial emissions to become the second largest source in the world after the electricity and heat sector.

4. Advantages and Disadvantages of SAF

As seen through the above information, the aviation industry has a significant impact on global carbon emissions. So far, the most viable mitigation strategy for achieving the net-zero emissions goal is use of sustainable aviation fuels. SAF would be a good step forward for sustainable aviation as a carbon-neutral substitute and intended drop-in fuel. SAF can be blended at 50% with the currently authorized drop-in fuels, resulting in a 40% reduction in CO₂ emissions. However, by using 100% SAF or hydrogen, CO₂ emissions can be significantly decreased. [6]. The use of sustainable aviation fuels will be responsible for 65% of the industry's emissions reductions by the year 2050, estimated by IATA. From raw material extraction, processing, transportation and end-use, a comparison of sustainable aviation fuels with conventional aviation fuels can have a CO₂ emission reduction of up to 80-85%, with little or no additional modification to existing aircraft and aviation infrastructure. Chemically, aviation fuels are composed of straight-chain and branched alkanes, with typical chain lengths ranging from C8 to C18, with an ideal chain length of C8 to C16. The main feedstocks for SAF include vegetable oils, algae, waste oils and animal fats, among others. Utilizing both virgin vegetable oils and remaining fats, oils, and greases, the hydrotreating of esters and fatty acids (HEFA), is the current method used for commercial SAF synthesis in the United States. However, a further catalytic breaking step is needed to transform long-chain fatty acids, principally C16 and C18, into C8 to C18 hydrocarbons suitable for jet fuel in order to produce HEFA SAF [7].

In other words, SAF is produced more sustainably by synthesizing it from alternate, renewable energy sources. Animal fats, tallow, algae, and vegetable oils are some of the raw materials used in SAF, but are ultimately converted into the same hydrocarbon mixture, kerosene. The properties of SAF are almost identical to petroleum-based jet fuel. They are molecularly identical, so they are combusted with equal efficiency. And Gurhan Andac, head of aviation fuels and additive manufacturing at General Aviation Group, said: "We need to make sure that SAF produced in a different way is comparable to Jet A and Jet A-1 fuels and does not adversely affect the operation and performance of the engine. As a result, we are actively providing test data acquired to support SAF qualification. This data comes from engine component and system testing at GE Aviation Group test sites in Peebles and Evandale, Ohio, and Lynn, Massachusetts, as well as other global sites. Additionally, it has been demonstrated that the low aromatic content of existing SAF routes minimize soot formation and aviation-related aerosol emissions by 50 to 70% [8].

However, one of the biggest barriers to the development of sustainable aviation fuels is cost (technology cost). According to an analysis by the International Council on Clean Transportation (ICCT), overall, the cost of producing sustainable aviation fuels from different technological routes is two to six times the current price of jet fuel. Since fuel costs account for 25% to 40% of the overall civil aviation industry operating costs, replacing current fossil fuels with sustainable aviation fuels will inevitably increase airlines' operating costs. At the same time, as mentioned earlier, a further catalytic cracking phase is necessary for the creation of HEFA SAF, which means that more oxygen is consumed, undoubtedly increasing costs. For CO₂ point sources, potential technological advances could reduce the cost of producing jet fuel to €2.5-3.3 per kg of fuel, while emissions could fall to 1.0 kg CO₂eq per kg of fuel. Taking into account current technology and carbon cost projections, the impact on the cost of an airline ticket would be at least 100-150% today and 40-80% by 2050. This shows that in order for SAF to remain competitive, future carbon levies will need to be at least €500 per tonne of CO₂ [9]. The other side of the coin is the credibility of SAF, specifically the attitude of various parties towards its full-scale use, as shown in fig.2. At the same time, as mentioned earlier, there must be an additional catalytic cracking phase in the synthesis of HEFA SAF, which means that more oxygen is consumed, which undoubtedly increases costs. Simply using fuel products that meet ASTM technical requirements does not guarantee sustainability; sustainable aviation fuel products still need to meet industry-recognized sustainability certifications such as International Sustainability & Carbon Certification and Sustainable Biomaterials. Sustainable Biomaterials. The Roundtable on Sustainable Biomaterials, which demonstrates overall reductions in carbon emissions through life cycle analysis, reports that HEFA fuels are the least expensive to produce of the mainstream

technology pathways mentioned above, but not all HEFA fuels reduce greenhouse gas emissions. The source of the fuel makes a very different difference: producing fuel from oilseeds such as sugarcane or palm oil not only costs more than petroleum jet fuel, but also produces more GHG emissions over its lifetime. Therefore, further research should focus on Fischer-Tropsch (FT), Alcohol-to-Jet (ATJ) and Hydro processing of Fermented Sugars (HFS) techniques to improve the economics of biojet fuel production and promote the commercialization of these technologies [9]. For the time being, HEFA remains the most favorable and only technology option because it has the highest efficiency. In addition, the direct use of vegetable oils as a feedstock for fuel production puts pressure on food security and can lead to land use changes such as deforestation.

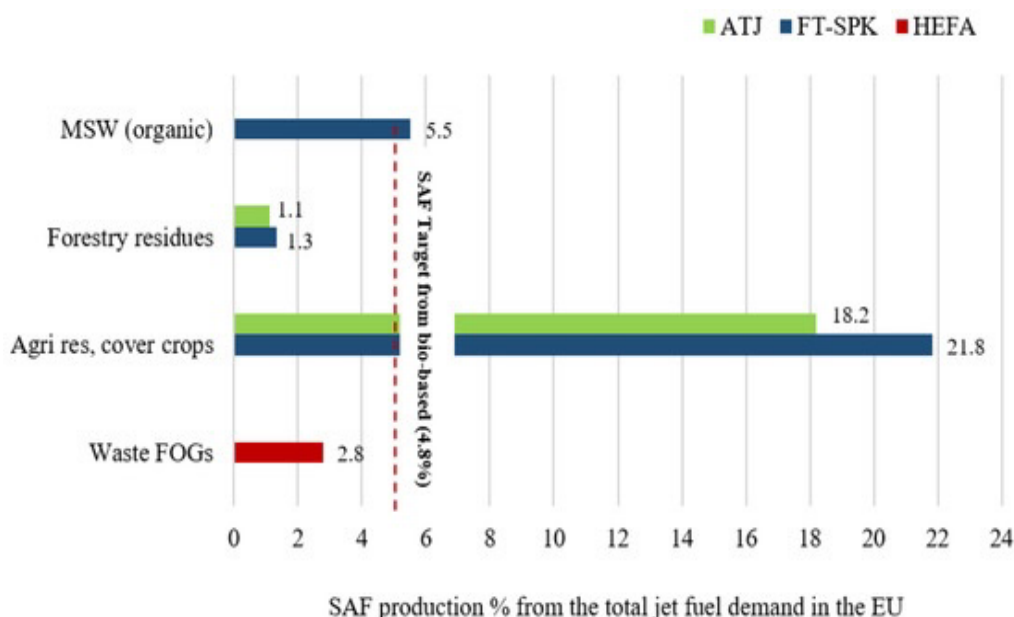


Figure 2. SAF production projections based on EU feedstock availability till 2030 [10].

5. Conclusion

Based on the above data, SAF will still not be able to replace most of the current aviation kerosene in the near future. However, there is a predictable trend of overshooting towards SAF. Fuel, which is the main cause of emissions in the aviation industry, will have to be completely replaced by SAF in the future, and although the benefits of SAF are very promising, there are still concerns about its cost. Therefore, at this stage, the first thing that needs to be done is to find more efficient ways of converting the raw materials and improving the technology if the goal is to be achieved. As for the trust issue, it will disappear naturally where the cost issue is solved. Today, governments are fully supporting the program, with financial and policy support, and organizations are creating strategies, rewards, rules, and regulations to help operators financially and encourage SAF. Major airlines are also responding to the government's call. For example, GE Aviation Group, a subsidiary of GE, has been a leader in technology research and development, and has been actively promoting the research and dissemination of sustainable aviation fuels to help the aviation industry achieve its emissions reduction goals. In short, SAF is obviously of great value as an alternative to green aviation energy. At present, governments, airline companies and industrial chain manufacturers all attach great importance to the investment and promotion of SAF. But at the same time, SAF is still a challenge to be fully promoted due to its high cost and limited supply.

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