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UNIVERSITY OF ŽILINA

SUSTAINABLE AVIATION FUEL FROM THE PERSPECTIVE OF LONG-TERM SUSTAINABILITY AND DEVELOPMENT

Kristína Šajbanová
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
sajbanova@stud.uniza.sk

Michal Janovec
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
janovec@fpedas.uniza.sk

Jana Zachar Kuchtová
Department of Informatics and Management
Academy of the Police Force in Bratislava
Sklabinská 1,
83517 Bratislava
jana.kuchtova@akademiapz.sk

Abstract

The aim of the article is to create a SWOT analysis of the position of sustainable aviation fuels (SAF) as an innovative available product on the aviation fuel market and to evaluate its development and application in the coming years. The motivation for the analysis and subsequent creation of this work is the fact that the topic of sustainable aviation fuels is currently extremely actual and also relevant for the future of air transport, as well as the future of the ecosystem from the point of view of reducing the emission load caused by the emissions of aircraft engines, which have a non-negligible share of the ecological load our planet. Because the combustion process in aircraft engines is the main factor in the creation of emissions, alternative aviation fuels from sustainable sources have been developed in order to reduce them. Thanks to the analysis of the goals of the influential aviation manufacturers, we found that the attention paid to the implementation of sustainable fuel is currently and will be given increased attention in the future. Achieving this goal will be made possible through technological advances and governance adjustments in many companies affecting aviation, from aircraft and fuel manufacturers to institutions dealing with administrative matters affecting aviation.

Keywords

fuel, emissions, sustainability

1. Introduction

Fluctuations in climatic conditions are mainly caused by the release of emission elements from human activity, which cause changes in the natural balance of element ratios in the atmosphere. These changes are, of course, unnatural for the planet and result in negative phenomena, and therefore global warming causing climate change. There are changes in climate temperatures that negatively affect the entire ecosystem. The development of alternative aviation fuels is therefore a non-negligible part of reducing the negative impact of air transport emissions on the environment. The most influential manufacturers of aeronautical technology have set goals with which they want to direct aviation on a sustainable path. One of their main goals is also to achieve the transition to 100% use of sustainable fuel. Some technologies already allow the use of 100% sustainable fuel, and in the near future the development of these technologies will increase thanks to the mutual cooperation of aircraft manufacturers. The implementation of SAF in the future requires minimizing the price as well as improving availability as much as possible, as well as simplifying certification and adjusting rules in individual segments of aviation to quickly and efficiently achieve the decarbonization of air transport.

2. Methodology

In order to predict the future state of SAF in the aviation sector, the form of SWOT analysis is applied. The purpose of a SWOT analysis is to assess the current state and create alternatives for the future development of the examined object. In order to achieve the result of the SWOT analysis, it was necessary to perform the following steps. In the first step, a general analysis of strengths, weaknesses, opportunities and threats was performed, which led to the selection of the most relevant parameters. Based on a thorough study of verified sources and scientific articles of renowned databases, a categorization of the determined parameters was subsequently carried out, resulting in a table of categorization of SAF elements.

Table 1: Schematic representation of the strengths and weaknesses of SAF, as well as its opportunities and threats. Source: Authors.

Strengths ○ Use of renewable feedstocks sources for production ○ Reduction of NOx and CO emissions ○ Carbon neutrality ○ Same fuel properties compared to Jet-A ○ Aircraft certified for the current specification of jet fuel can use SAF	**Weaknesses** ○ Higher cost (2-5 times higher price) ○ More inaccessible in opposition to conventional fuel ○ Low volume of production
Opportunities ○ Enabling the use of 100% blend of SAF in the near future ○ Accelerating the development of new technologies for reduction of fuel consumption ○ Raise of new job opportunities ○ Strengthening of the agricultural sector	**Threats** ○ Land occupation ○ Increase in the cost of flying

2.1. Analysis of strengths

2.1.1. Use of renewable feedstocks sources for production

These resources include corn grain, oil seeds, algae, other fats, oils, and greases agricultural residues forestry residues wood waste, urban solid waste stream, wet wastes (manures, wastewater treatment sludge), special energy crops. This broad resource contains enough raw materials to meet the needs for aviation industry, provide additional quantities of low carbon fuels for other modes of transportation, and produce high-quality bio-products and renewable chemical compounds.

2.1.2. Reduction of NOx and CO emissions

The sustainable combustion of aviation fuel reduces NOx and CO production compared to fossil fuels. These compounds were measured in experiments using a mixture of fossil fuels and SAF in an engine under the same conditions. The results showed a 38% reduction in NOx and a 44% reduction in CO compared to Jet-A. SAF has the potential to achieve a CO2-neutral life cycle, reducing CO2 impacts by 80%.

2.1.3. Carbon neutrality

SAF's arguments are convincing. It reduces life-cycle CO2 emissions by around 80%, and this number is expected to increase significantly over the next few years. It is possible to generate negative carbon SAF.

2.1.4. Same fuel properties compared to Jet-A - aircraft certified for the current specification of jet fuel can use SAF

SAF can be produced using a variety of techniques that use physical, biological and chemical reactions to break down biomass and waste resources and recombine them into energy-dense hydrocarbons. As with conventional jet fuel, the hydrocarbon mixture in the SAF must be tuned to achieve the key properties required for safe and reliable aircraft operation.

Working with biorefineries, aerospace companies and farmers, researchers are developing new ways to produce SAF from renewable and waste feedstocks that meet stringent fuel specifications used in existing aircraft and infrastructure. The laboratories works with industry partners to develop SAF pathways and fuel formulations for the testing and certification required to ensure these fuels are fully compatible with existing aircraft and infrastructure.

2.1.5. Reduction of CO2 during combustion process

CO2 reduction during combustion process is minimal, but the problem of CO2 emissions is solved by SAFs carbon life cycle ability.

As part of the established SWOT analysis methodology, a matrix of the importance of strengths was created, which formed the basis for the subsequent evaluation of the parameters.

Table 2: Matrix of strengths importance. Source: Authors.

		Effect (value)	
		High	**Low**
Importance	**High**	○ Use of renewable feedstocks sources for production ○ Carbon neutrality ○ Same fuel properties compared to Jet-A ○ Aircraft certified for the current specification of jet fuel can	○ Reduction of NOx and CO emissions ○ Reduction of CO2 during combustion process
	Low		

On the basis of the above-mentioned table, the identified strengths were assessed, while the values of the "value" and "scale" parameters were determined based on the number of scientific articles, the contents of which determined the strengths of SAF. The total number of reviewed scientific articles related to SAF was 68. The value of the parameter "scale" represents its importance and the value of the parameter "value" to what extent the parameter is currently valid and represents the real state of the problem.

Table 3: Assessment of identified strengths. Source: Authors.

	Value <1-5>	**Scale (0-1)**	**Calculated values**	**Maximal values**
Use of renewable feedstocks sources for production	4	0,3	1,2	1,5
Reduction of NOx and CO emissions	5	0,2	1	1
Reduction of CO2 emissions during combustions process	4	0,3	1,2	1,5
Carbon neutrality	3	0,05	0,05	0,25
Same fuel properties compared to Jet-A	3	0,05	0,15	0,25
Aircraft certified for the current specification of jet fuel can use SAF	4	0,1	0,4	0,5
OVERALL	**-**	**1,00**	**4,0**	**5**

2.2. Analysis of weaknesses

2.2.1. Higher cost (2-5 times higher price)

Current costs of sustainable aviation fuel are 2-5 times higher than conventional fossil fuel. Airlines used about 100 million litres of sustainable aviation fuel in 2021 which is a small amount compared to the total fuel required for the aviation industry. Airlines had ordered 14 billion litres of SAF. This happened despite the fact that the price of SAF was about two and a half times the price of fossil kerosene.

2.2.2. More inaccessible in opposition to conventional fuel

Currently, the availability of SAF is lower compared to conventional fuel, but this deficiency is one of the problems that aircraft manufacturers and institutions will eliminate in the near future.

2.2.3. Low volume of production

SAF is already offering a resources with 78 000 tonnes produced and used in 2021, with expected production capacity raising to 4 million tonnes by 2025 which means 100 times increase. Nevertheless, to obtain a net zero target for air transport by 2050 it is likely that a production capacity of the order of 500 million tonnes of SAF would be required in 2050, which is another 100 times increase opposite to 2025.

2.2.4. Land occupation of food crops

There are crops considered as source for feedstocks with ability to grow in water environment or in inhospitable places such as deserts.As in the case of positive aspects, also in the case of SAF weaknesses, an importance matrix was compiled, which served as a basis for the subsequent evaluation of the parameters.

Table 4: Matrix of weaknesses importance. Source: Authors.

		Effect (value)	
		High	**Low**
Importance	**High**	○ Higher cost ○ Low volume of production	
	Low	○ More inaccessible in opposition to conventional fuel	○ Land occupation of food corps

Subsequently, based on the above-mentioned matrix, an assessment of the identified weaknesses was created.

Table 5: Assessment of identified weaknesses. Source: Authors.

	Value <1-5>	Scale (0-1)	Calculated values	Maximal values
Higher cost (2-5 times higher price)	5	0,5	2,5	2,5
More inaccessible in opposition to conventional fuel	2,5	0,1	0,25	0,5
Low volume of production	4	0,2	0,8	1
Land occupation of food crops	0	0,2	0	1
OVERALL	-	**1,00**	**3,55**	**5**

2.3. Analysis of SAF opportunities

2.3.1. Enabling the use of 100% SAF in the near future

Most major aerospace companies agree that aviation agencies should allow 100% SAF blends, as only 50% SAF blends with fossil fuels are currently allowed. Allowing the use of 100% SAF could lead to increased use of SAF by airlines, which would lead to higher SAF consumption and demand for SAF. Higher consumption and demand will lead to more investment in the SAF sector, which can grow and improve faster.

2.3.2. Accelerating the development of new technologies for fuel consumption reduction

Higher price of sustainable aviation fuel can mean greater demand for the engines with lowest possible consumption, this fact can lead to effort of manufacturers to speed up the technological improvements of engines.

2.3.3. Raise of job opportunities

Expanding SAF domestic production may help sustain the interests of biofuel industry and create new economic benefits by creating and securing job opportunities. These include jobs in:

- Feedstocks production in agricultural communities
- Construction for building advanced biorefineries
- Manufacturing for operating SAF biorefineries and infrastructure
- Aviation, including pilots, aircrew members, maintenance personnel and other industry professionals.

2.3.4. Strengthening of agricultural sector

Growing, sourcing and producing SAF from renewable and waste sources can create new economic opportunities for farming communities and improve the environment. By growing biomass crops for SAF production, farmers can make more money by providing raw materials for this new market, while ensuring their farms benefit, such as reduced nutrient losses and improved soil quality.

The opportunities listed above are again placed in a matrix of importance.

Table 6: Success probability of SAF opportunities based on their attraction. Source: Authors.

Importance		Effect (value): High	Effect (value): Low
	High	○ Enabling the use of 100% blend of SAF in the near future ○ Raise of new job opportunities ○ Strengthening of the agricultural sector	
	Low	○ Accelerating the development of new technologies for reduction of fuel consumption	

All mentioned opportunities of SAF application have been discussed in detail several times in scientific articles. The greatest importance was attributed to the possibility of using 100% SAF mixture as well as the possibility of developing new technologies. It is for this reason that they are assigned a value of 5 on a scale of 1-5 in the assessment table of the identified options. Many scientific articles have dealt with the impact of SAF development on the agricultural sector as well as in relation to the impact on employment in the agricultural sector. Since the direct impact of the introduction of SAF on employment in the agricultural sector has not been directly proven and is only marginally mentioned in the scientific literature, it is assigned a value of 3 in the calculations.

Table 7: Assessment of SAF opportunities. Source: Authors.

	Value <1-5>	Scale (0-1)	Calculated values	Maximal values
Enabling the use of 100% blend of SAF in the near future	5	0,3	1,5	1,5
Raise of new job opportunities	3	0,25	0,75	1,25
Low volume of production	4	0,3	1,2	1,5
Accelerating the development of new technologies for reduction of fuel consumption	5	0,15	0,75	0,75
OVERALL	-	**1,00**	**4,2**	**5**

The last step was the evaluation of possible threats and therefore external aspects of the development and application of SAF from the point of view of long-term sustainability.

2.4. Analysis of threats

2.4.1. Land occupation

The International Air Transport Association (IATA) claims that there are significant concerns in some quarters that increased SAF intake could lead to severe deforestation and lead to shortage of crops vital to food production. The head of the IATA believes it is crucial that the industry does not use raw materials that compete with land use or food production. Any regulation related to the long-term development of sustainable aviation fuels will ensure that this is not the case.

2.4.2. An increase in the cost of flying

Sustainable aviation fuel is 2-5 times more expensive than conventional fuel, but plenty of consumers are willing to pay, therefore orders for sustainable aviation fuel increases. This fact may result in more expensive flights overall, therefore mirrored on the higher prices of air tickets of airliners. However the more SAF is implemented to the aviation, the faster the development of this sector will be in future, resulting in normalization of SAF costs.

Table 8: Effects of SAF threats based on their importance. Source: Authors.

Importance		Effect (value): High	Effect (value): Low
	High		○ Increase in the cost of flying
	Low		○ Land occupation

In the last step of the SWOT analysis, we identified only 2 threats to SAF. Since most of the scientific articles that served as a basis for the creation of the matrix were devoted to the impact of the SAF price on ticket prices or the total price of the flight, and indicated a favourable development of the price of flights using SAF, a value of 1 is assigned. Likewise, in the case of the land occupation aspect, most articles deal with alternative options production of SAF, such as the use of crops capable of growing in deserts, or the use of algae as a basic raw material, which in its essence does not need land for cultivation. Since a direct land occupation threat has not been proven the aspect has reached a value of 0.

Table 9: Assessment of SAF threats. Source: Authors.

	Value <1-5>	Scale (0-1)	Calculated values	Maximal values
Increase in the cost of flying	1	0,7	0,7	3,5
Land occupation	0	0,3	0	1,5
OVERALL	-	**1,00**	**0,7**	**5**

3. Results

The final balance of the observed parameter is obtained by subtracting the value of weaknesses from the final value of strengths. The same calculation method is applied for the parameters of opportunities and threats.

$$\Sigma S - \Sigma W = 4 - 3{,}55 = 0{,}45$$

$$\Sigma O - \Sigma T = 4{,}2 - 0{,}7 = 3{,}5$$

As we can see in the graphic representation of the SWOT analysis results, SAF tends to outweigh negative influences with its advantages. We can observe this fact by position of the resulting SWOT analysis value in the quarter of strengths. The result indicates a positive development of the SAF in aviation, since the negatives of the SAF are less significant factors compared to the positive influences.

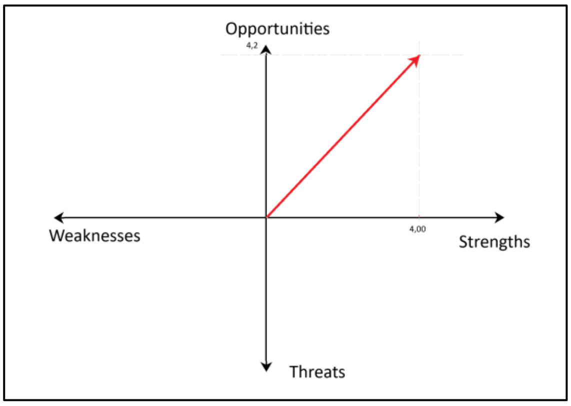

Figure 1: Final evaluation of SWOT analysis depicted in quartals.
Source: Authors

4. Discussion

For decades we have continuously dedicated ourselves to improving the efficiency of our engines, taking each working part and making it better, shaving fractions of a percent off the amount of fuel burnt. The effort to achieve lower consumption of fuel and efficiency of engines were one of the main goals for decades. While alternative technologies such as hydrogen and electric propulsion can be suitable for use in commercial aviation, when these technologies are mature enough to introduce passenger service, larger aircraft flying long-haul flights will be only able to use SAF for emission neutralization. Further research should allow SAFs to replace 100 % of fossil fuel-based kerosene in the coming years. SAF is already offering a resources with 40 kilotons produced in 2019 and with expected production capacity raising to 4 million tonnes by 2025 it means 100 times increase. Aerospace companies are working to assure that all new aircraft and power plants can run on 100 % SAF blends by 2030. Also airports are ensuring airport infrastructure is SAF prepared. Aviation airworthiness and safety organs are making more simple the licensing of higher mixtures percentages and certifying new kinds of SAF.

5. Conclusion

The development of alternative aviation fuels is an essential part of reducing the negative environmental impact of aviation emissions. Thanks to the SWOT analysis, we found that the attention paid to the implementation of sustainable fuel is currently and continuously given increased attention. Achieving this goal will be possible through technological progress and adjustments to governance rules in many corporations affecting aviation operations, from aircraft and fuel manufacturers to institutions dealing with administrative matters affecting aviation. By comparing and explaining the carbon life cycle of the alternative fuel, a justification of its sustainability was achieved on the basis of the same carbon dioxide consumption in production, distribution and the same amount of emission exclusion in the fuel consumption of aircraft engines. The most effective implementation of the SAF in the future also requires minimizing the price as much as possible, improving its availability worldwide, and simultaneously simplifying certification and regulatory adjustments in individual aviation segments to achieve decarbonisation of air transport quickly and efficiently.

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