

PERSPECTIVE

The future of the development and use of alternative jet fuels from the aspect of air space decarbonization

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Abstract

In the last decades of the twentieth century, the development and use of sustainable alternative jet fuels emerged as a key factor in reducing the decarbonization of the airspace (reducing aviation-related CO₂ emissions). “Refuel Aviation” initiative promotes the development and use of sustainable aviation fuels of SAFs (sustainable aviation fuels) for the decarbonization of air traffic, highlighting the obligation of suppliers to increasingly sell sustainable fuels at all airports within the EU. Compared to the CO₂ emission produced during the flight of an airplane with conventional hydrocarbon fuel (kerosene), using alternative jet fuels, it is possible to reduce this emission by up to 80%, depending on the type of raw material used and the method of sustainable fuel production. The International Aviation Transport Association has updated the strategy developed in four stages, the main goal of which is that aircraft have 0% greenhouse gas emissions by 2050. The use of hydrogen as an alternative jet fuel with “zero CO₂ emissions” is considered very interesting, because it can be produced without the generation of CO₂, and in addition, it is present in water in large quantities. On the other hand, for the application of H₂ required is a special airport and transport infrastructure. In addition, today there are a number of challenges and concerns related to the production and implementation of H₂ in the aerospace industry. The paper gives a brief overview of the future of development and the obligation to use alternative jet fuels from the aspect of airspace decarbonization. In addition, progress and further predictions in aviation were highlighted.

Keywords: alternative jet fuels, decarbonization, future, development

1. INTRODUCTION

Due to the increasing pollution of the environment, both industry and aviation are turning to new environmentally friendly energy sources that will primarily affect the reduction of greenhouse gas emissions, bring a number of other advantages and improvements compared to fossil fuels that are mostly used in today’s aviation (Arsenović, Janjuš, & Banjac 2012).

According to statistical data on air operations, transported passengers², cargo and mail at airports in BiH (III quarter of 2023 to III quarter of 2024), an increase of 8.9% in airport operations compared to the same quarter

of the previous year was confirmed, Figure 1. The number of transported passengers is higher by 5.0% compared to the same quarter of the previous year, and the amount of transported goods is lower by 7.5% compared to the same quarter of 2023. The amount of mail transported by air in the third quarter of 2024 shows an increase of 33.9% compared to the same quarter of the previous year. The data were processed in accordance with the statistical program and standards of the International Civil Aviation Organization (ICAO)³.

It is well known that the need for fuel in air transport is very high, which is why more and more investments are

²Count all passengers on a specific flight (under the same flight number) only once, and not again on each part of that flight (Agency for Statistics of Bosnia and Herzegovina 2024).

³All data on the number of passengers, cargo and mail refer to international air traffic, because there is no domestic air traffic in BiH (Agency for Statistics of Bosnia and Herzegovina 2024).

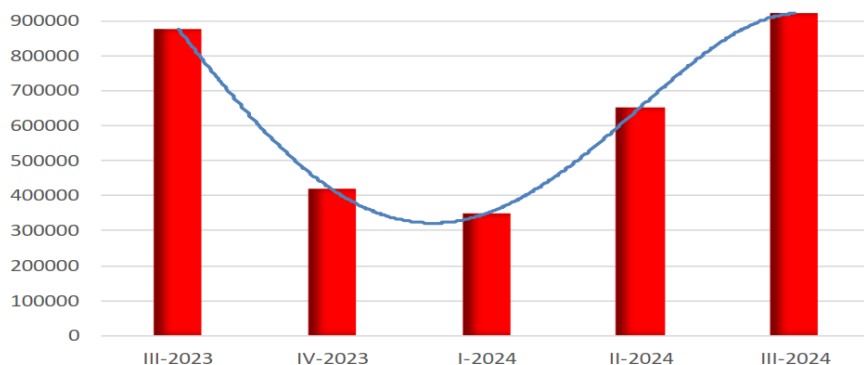


Figure 1. Graphic representation of the number of transported passengers in air transport for the 3rd quarter from 2023 to 2024 in Bosnia and Herzegovina.

being made in the development of its technologies and environmentally friendly fuels (Arsenović 2019).

2. INTERNATIONAL LEGAL REGULATION IN THE FIELD OF EMISSIONS OF HARMFUL SUBSTANCES IN AIR TRAFFIC

The level of emissions of harmful substances in air transport was first regulated by an international agreement adopted in Stockholm in 1972, issued by International Civil Aviation Organization (ICAO), and later expanded by various additions. This is Annex 16 called “Environmental Protection” where emissions of harmful substances are prescribed in “Volume II”, while the regulation of noise issues is shown in “Volume I”. Later, the agreements were extended to the global level. A significant step in reducing emissions of harmful substances was made in 2005 in Kyoto, under the name Kyoto Protocol. The protocol required industrial countries listed in Annex 1 to reduce greenhouse gas emissions. In 2007, an ICAO meeting was held at which both developed and developing countries were required to change their policy on reducing emissions of harmful substances and to find stable solutions to the growing problem of emissions and to submit solutions as soon as possible to the United Nations Framework Convention on Climate Change (UNFCCC).

In 2016, the Paris Agreement on climate change was reached, the main elements of which are: reduction of emission levels⁴, transparency of measurements and emission levels; adaptation of countries according to the Paris Agreement; increased cooperation between various sectors related to climate change; greater interest of cities, regions and authorities and giving incentives to developed countries. Committee on Aviation Protection (CEAP) is in charge of regulating emissions of harmful substances and noise in air transport.

⁴(New York City Department of Transportation 2023)

At the CEAP meeting, in Montreal in February 2016, under the name CEAP/10, new measures were adopted to regulate the emission of harmful substances, noise, operations at airports, insight into the global fossil fuel market and, finally, incentives for the use of alternative fuels, so that be in global application by 2050. CEAP consists of 24 members and 15 observers. Over 600 experts from different countries participate in its program. ICAO takes over the database on harmful emissions from aircraft engines from European Aviation Security Agency (EASA).

An important step in the control of emissions of harmful substances is the Clean Sky program, which, with the help of the latest technology, intends to reduce the negative emissions of air traffic (noise and emissions of harmful gases). The goal of the Clean Sky program is to enable the progress and competitiveness of the European fleet on a global level through its implementation, and it is financed by Horizon 2020. The Clean Sky project was launched in 2008 (Clean Sky 1 was successfully completed). Since 2017, the Clean Sky 2 project (successor to the 1st project) has been in the implementation phase.

The technological achievements developed during the Clean Sky 1 project are:

- smart fixed wing of the aircraft;
- sustainable and “green” engines;
- “green” regional aircraft;
- “green” rotorcraft;
- systems for “green” operation of aircraft operations;
- ecological design of the previously mentioned achievements of Clean Sky 1; and
- technological evaluation program.

The Emissions Trading System (EU ETS) is the largest European organization whose goal is to reduce the emission of harmful substances in air traffic for the prevention of climate change, and it consists of 31 countries. This organization aims to reduce emissions of harmful substances emitted by air carriers with minimal costs, which

is a very important factor in the use of “green” technologies (Arsenović 2024).

2.1. Greenhouse gas reduction goals

In order to reduce greenhouse gas emissions, in 2007 International Aviation Transport Association (IATA) updated its strategy, the main goal of which is for airplanes to have 0% greenhouse gas emissions by 2050. That strategy consists of four phases:

- technology improvement and high commitment to low-carbon fuels,
- improvement of aircraft operations,
- better infrastructure in airports,
- economic measures, in order to reach the global market and cover other emissions.

In 2009, IATA set some more goals:

- the limit for the level of CO₂ emissions after 2020,
- improvement of fuel efficiency by 1.5% per year (from 2009 to 2020),
- reduction of CO₂ emissions by 50% by 2050.

In order to achieve the stated goals, in 2016, ICAO launched the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) initiative, which is a “scheme” for reducing greenhouse gases at the global level. From 2021 to 2026, voluntary implementation of CORSIA requirements has been approved, and after 2026, these requirements become mandatory. 65 countries have already accepted the CORSIA requirements, which will affect the reduction of about 80% of CO₂ from 2021 to 2035 (Arsenović 2024). The plan for reducing CO₂ emissions from 2010 to 2040 is shown in Figure 2.

Although improvements in aircraft design and in-flight operations can significantly reduce CO₂ emissions, the problem is still the extremely high growth in air traffic globally. As can be seen from Figure 2, a reduction in carbon emissions is expected from 2020, and in order to achieve this, the only close solution so far is “drop-in” fuel.

Sustainable aviation fuels are aviation fuels that include liquid “drop-in” fuels that are fully interchangeable with, compatible with, and interchangeable with conventional aviation fuels and existing aircraft engines, as well as hydrogen and electricity. SAF or biofuel is a “drop-in” fuel. Globally, several sustainable variants of this type of fuel have been certified for use in civil and military aviation. It is also expected that this type of fuel will represent the majority share of the aviation fuel mix in the coming decades.



Figure 2. Graphic representation of the plan to reduce CO₂ emissions until 2040 in air traffic.

3. ALTERNATIVE FUELS

3.1. Sustainable aviation fuel – SAF

Sustainable Aviation Fuel (SAF) is the main name used by the aviation industry to represent non-conventional aviation fuel.

IATA has accepted this definition, but also accepts other definitions used for these types of fuels such as: alternative fuels, sustainable alternative jet fuels, renewable jet fuels, considering that fuels can also be produced from other non-biological and chemical sources. A term that is also used is biofuel, but it refers to fuels that are produced from biological resources, most often plant materials. According to the definition accepted by ICAO, an alternative fuel is: “any fuel that has the potential to generate lower carbon emissions than conventional kerosene on a life cycle basis”. Also, ICAO uses the definition that alternative fuel is any fuel that is not based on petroleum, which includes liquid fuel from coal, and fuel produced from natural gas, but their production itself emits the same or more harmful substances than is emitted in the production of fuel from petroleum.

By Regulation (EU) 2021/119, the Union established legal obligations to achieve climate neutrality by 2050 at the latest, as well as to reduce net greenhouse gas emissions by 2030 by at least 55% compared to 1990. In order to achieve this, all economic sectors, including the transport sector, must take rapid steps to decarbonise (European Parliament 2022).

Pursuant to Amendment 102 – Annex 1, adopted by the European Parliament on 7 July 2022 (Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport (COM(2021)0561-C9-0332/2021-2021/0205 COD)

the minimum shares of SAFs were determined, including the minimum share of synthetic aviation fuel⁵, Table 1.

Table 1. Minimum shares of SAFs including the minimum share of synthetic aviation fuel.

Aviation fuel available to all aircraft operators at all airports of the Union with minimal content of sustainable aviation fuel (SAFs), including a minimum content of synthetic aviation fuel

a) From 1 January 2025	Min. SAF share 2%; of which synthetic fuels min. 0.04%.
b) From 1 January 2030	Min. SAF share 6%; of which synthetic fuels min. 2%.
c) From 1 January 2035	Min. SAF share 20%; of which synthetic fuels min. 5%.
d) From 1 January 2040	Min. SAF share 37%; of which synthetic fuels min. 13%.
e) From 1 January 2045	Min. SAF share 54%; of which synthetic fuels min. 27%.
f) From 1 January 2050	Min. SAF share 85%; of which synthetic fuels min. 50%.

3.2. Criteria for the potential use of alternative fuels in air traffic

In order for alternative fuels to start being used in air traffic in commercial transport, or in some other type, it is necessary that they meet certain criteria. Apart from the need for an equal or higher energy value than the current aviation fuel, and of course, the reduction of greenhouse gas emissions, which is constantly increasing due to the increase in the volume of transport, the main criteria for the potential use of alternative fuels in air transport are British Ministry of Defense Standard DEF STAN 91-091, 2016, 2019, 2022 (British Ministry of Defence 2016, 2019, 2022):

- characteristics of the fuel itself,
- ecological effects,
- mass production,
- economic justification,
- security of use and compatibility.

The first criterion is that alternative fuels should have the same or better characteristics than hydrocarbon commercial fuels of the kerosene type (JET A-1 and others). This is the reason that air carriers do not have to modify the engine or structure of the aircraft, and that the

⁵“Synthetic aviation fuels” means hydrogen from renewable sources, electricity from renewable sources or fuels that are renewable fuels of non-biological origin (European Parliament 2022)

method of fuel supply does not change. The characteristics of the fuel itself include, among others, the weight of the fuel. Fuels that require larger tanks and are much heavier than currently used fuels are not currently acceptable in air traffic, such as liquid hydrogen.

The second criterion is environmental effectiveness when using alternative fuels. One of the main goals of using alternative fuels is the reduction of greenhouse gas emissions, and therefore replacing current aviation fuels with some fuel that will have more pronounced emissions of these gases is unacceptable.

The third criterion is mass production. If the alternative fuel meets all the criteria, without the possibility of mass production, that fuel is not suitable for use in commercial air traffic. For the use of sustainable alternative fuels in air traffic, it is necessary to have large areas intended for the cultivation of biomass, i.e. raw material that serves as fuel. A way to ensure the production of biomass that can meet the needs of commercial traffic is to focus on lands that are not suitable for growing food, plants that do not require pesticides, compost or irrigation and most importantly, that they do not affect the ecological system in which they are located. For example, a plant that is not edible, does not require a large infrastructure or care is algae. The mentioned characteristics for biomass production can be fulfilled, but the problem in realizing the production is related to economic justification.

The fourth criterion of economic justification is also the reason why alternative fuels are not yet in global use in air transport.

The fifth criterion is safety of use and compatibility. Fuel that freezes quickly at low temperatures, has a low auto-ignition temperature, or is the result of a complicated production process and transportation to the aircraft tank itself, is not suitable for use.

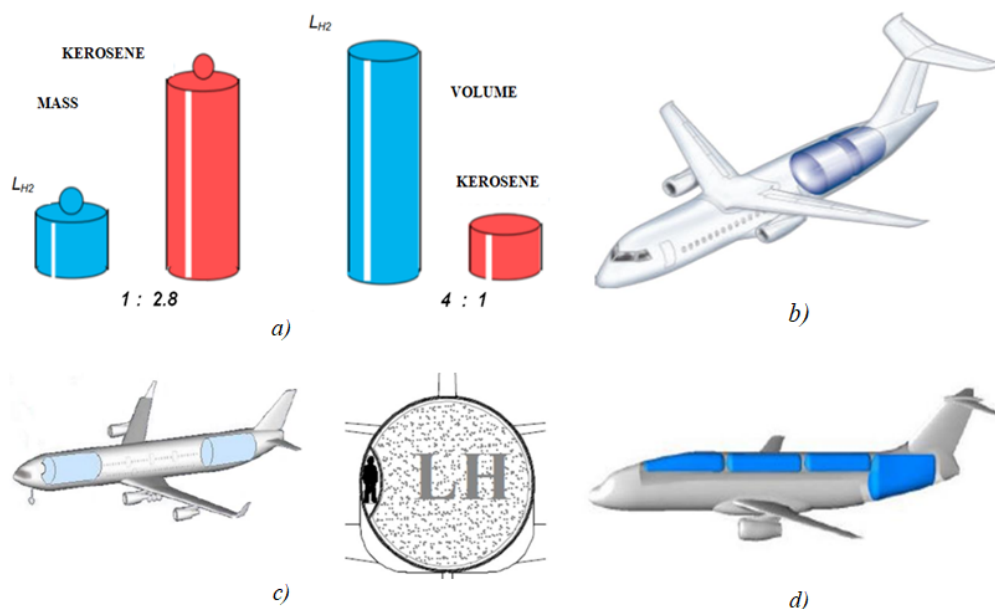
The main goal of using alternative fuels in air traffic is that the safety of use tends to be similar to that of current aviation fuel or to be of even better quality. Apart from safety, it is important that the fuel does not significantly affect the structure of the engine, the aircraft or the airport infrastructure itself.

4. HYDROGEN AS AN ALTERNATIVE SOURCE OF ENERGY

Hydrogen, as an alternative source of energy, is considered both in our country and in the world, as one of the future environmentally friendly sources of energy, with the fact that it can be used as a raw material, fuel and energy carrier, and in addition, it has a wide application in industry, energy and transport. It is important to emphasize that hydrogen does not emit CO₂ and does not

Table 2. Comparison of characteristics of kerosene (Jet A-1) and cryogenic hydrogen.

Property	Jet A-1	Cryogenic hydrogen (LH ₂)	Consequences
Boiling temperature (°C)	167–266	–253	frostbite, evaporation of H ₂ , brittleness of material
Flammability limit (%)	0.6–4.7	4–75	high probability of H ₂ fire, where a higher concentration is required to start it
Minimum energy ignition (MJ)	0.25	0.02	higher probability of H ₂ fire caused by weak sparks
Burning speed (cm/s)	18	265–325	fire caused by H ₂ burns faster than fire caused by kerosene
Thrust	–	14× lighter than air, rises to 20 m/s	hydrogen in gaseous state dissolves quickly
Temperature self-ignition (°C)	210	585	is more difficult to ignite with pure heat
Radiation fraction fire	30–40%	10–20%	fires caused by H ₂ are less destructive because they release less heat; challenge due to invisible flames

**Figure 3.** Comparison of the difference in mass and volume of kerosene and hydrogen (a); position of hydrogen tanks in regional aircraft (b); the position of the tank in case of large variations in weight (c); and the position of the tank of short- and medium-range aircraft (d).

pollute the air during use. It is considered a solution for decarbonization, both in aviation and in other industrial sectors (extremely important in the implementation of the climate neutrality policy).

At the EU level, there are a number of documents, guidelines and initiatives related to the implementation of hydrogen in air transport. Some of the key documents are (European Union 2020):

- European Green Plan;
- Report on the aviation strategy for Europe;
- European Hydrogen Strategy.

Advantages of using liquid hydrogen: Advantages of using liquid hydrogen are zero CO₂ emissions; low emissions of harmful substances; high energy efficiency

per mass; acceptable ecological production; noise reduction and flight safety.

Disadvantages and challenges in the application of hydrogen: Aircraft modifications – hydrogen-powered aircraft carry a larger volume of fuel compared to kerosene-fueled aircraft, Figure 3. One of the important parameters is the diameter of the tank and its influence on the gravimetric efficiency (filling of the tank with hydrogen during takeoff and landing compared to conventional fuel) (Huete & Pilidis 2021).

Infrastructural requirements and adaptation of airports – the challenge of supplying and filling with liquid hydrogen at airports.

5. CONCLUSION

Alternative fuels in air transport represent a new generation of fuels. Given that the increase in passenger and freight traffic is increasing, slight modifications aimed at reducing emissions of greenhouse gases and harmful substances cannot cope with such an increase. In addition to having a significant impact on air quality, greenhouse gases also affect global warming, which is one of the most pressing problems today. To prevent such growth, change is needed. The use of hydrocarbon jet fuels of the kerosene type does not make any difference in reducing CO₂ and NO_x emissions.

The use of SAF appears as one of the answers to the reduction of greenhouse gas emissions, primarily CO₂ emissions. All sustainable alternative fuels must meet certain criteria, starting from ecological and economic justification to safety of application, and most importantly, reduced emissions of pollutants, and the possibility of sustainable sources of raw materials. Today, biofuels represent the closest option, and only second and third generation biofuels.

For the sake of easier access to the market, the only close solution so far are “drop-in” fuels, where their application will be accompanied by minimal or no modifications to the aircraft and engine construction. For the application of H₂, as an aviation fuel, a special airport and transport infrastructure is required. In addition, today there are a number of challenges and concerns related to the production and implementation of H₂ in the aerospace industry.

REFERENCES

Agency for Statistics of Bosnia and Herzegovina. (2024). [Title not provided in source] (XV/III). Sarajevo.

- Arsenović, B. (2019). Physico-chemical characteristics of JET A-1 fuel and lubricants for jet engines and their impact on the environment. In *Proceedings of the XIX International Conference: Innovation and Research in the Function of Technical-Technological Changes in Traffic, Ecology and Logistics*, Travnik.
- Arsenović, B. (2024). Some issues of development and application of sustainable aviation fuel (SAF) from the aspect of reducing CO₂ emissions. In *Proceedings of the XVII International Scientific Conference: Modern Materials*, ANURS, Banja Luka.
- Arsenović, B., & Banjac, E. (2011). Ecological aspects of aircraft exhaust gases affect in sum of green-house atmosphere gases. In *Proceedings of the International Conference on Innovative Technologies (IN-TECH 2011)*, Bratislava, Slovakia.
- Arsenović, B., Janjuš, Z., & Banjac, E. (2012). The influence of aircraft exhaust gases on the sum of atmospheric greenhouse gases. In *Proceedings of the XIV YUCORR*, Tara.
- British Ministry of Defence. (2016, 2019, 2022). *DEF STAN 91-091: Turbine fuel, aviation kerosene type, Jet A-1*, NATO Code F-35, Joint Service Designation AVTUR (Issues 9, 11, 14).
- European Parliament. (2022). *Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport* (Annex 1, Amendment). European Parliament.
- European Union. (2020). *Hydrogen-powered aviation: A fact-based study of hydrogen technology, economics, and climate impact by 2050*.
- Huete, J., & Pilidis, P. (2021). Parametric study on tank integration for hydrogen civil aviation propulsion. *International Journal of Hydrogen Energy*, 46(74), 37049–37062. <https://doi.org/10.1016/j.ijhydene.2021.08.194>
- New York City Department of Transportation. (2023). *Alternative fuel*. Retrieved July 21, 2023, from <https://www.nyc.gov/html/dot/downloads/pdf/alternativefuel.pdf>