Incheon Airport

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TOPIC

Impact of SAF on the Aviation Industry and Tasks

Sustainable Aviation Fuel and Roles of Incheon International Airport in Climate Crisis Response

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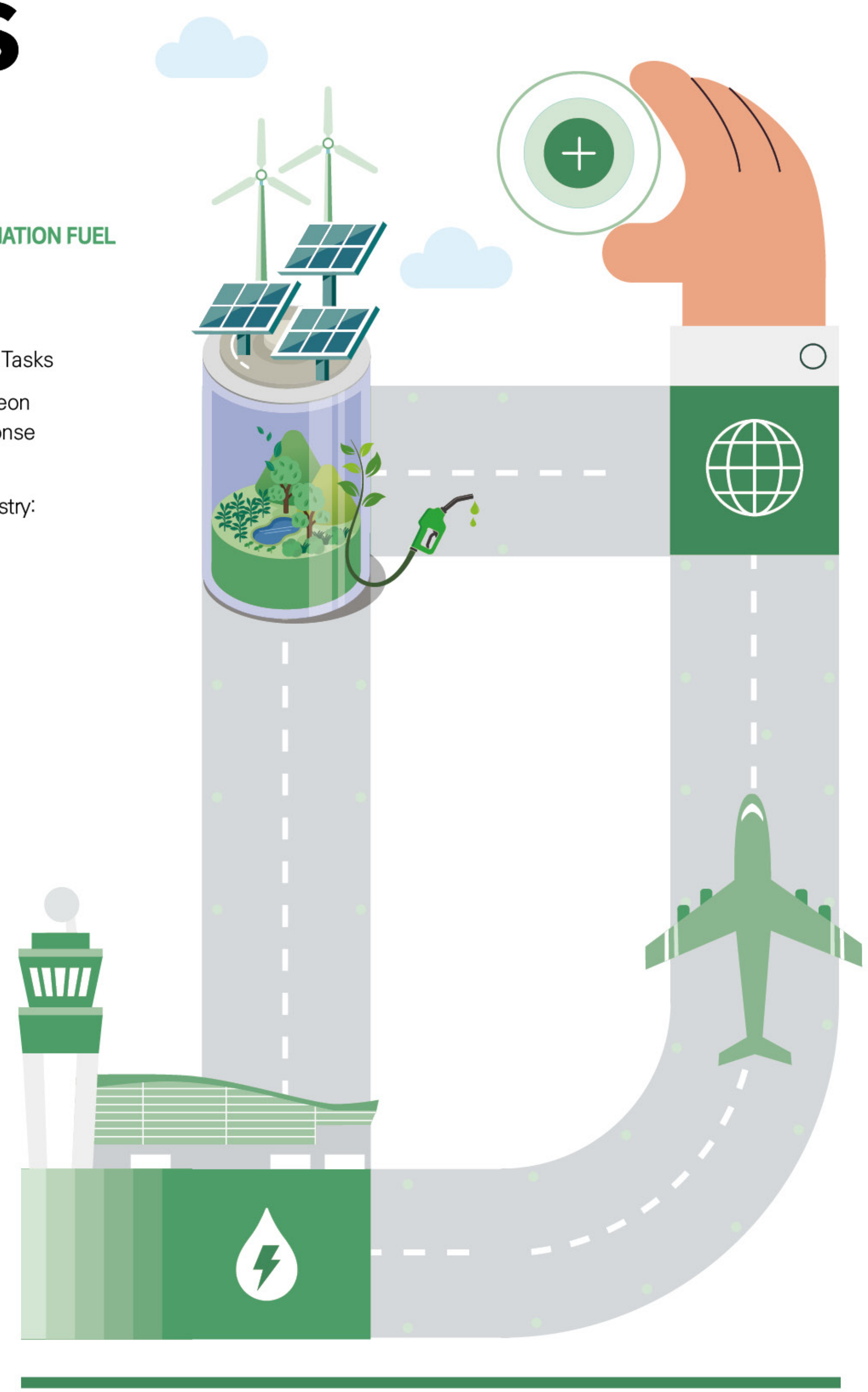
Impact of SAF Introduction on the Aviation Industry: Focusing on Airline Management



AIR WE CONNECT LIVES, CULTURES AND THE FUTURE.

Incheon Airport

TOPIC

Impact of SAF on the Aviation Industry and Tasks

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Since the invention of aircraft, the aviation industry has developed continuously by providing assistance to the long-distance transport of people and freight. Despite the ups and downs caused by various external factors such as natural disasters, extreme weather, pandemic, war, terrorism, and global financial crisis, the aviation industry has recorded fast and steady growth considering its relatively short history, and it is expected to grow continuously in the future. However, there are a number of issues that hinder the sustainable future of the aviation industry; in particular, environmental issues are considered serious. Accounting for the largest portion in the cost of aircraft operation, aviation fuel is expected to be a critical issue both environmentally and financially. Therefore, the importance of sustainable aviation fuel (SAF)–as opposed to the existing fossil fuel-based aviation fuel–is forecast to be amplified in the future. As an alternative to the existing aviation fuel, SAF is seen to provide environmental efficiency and ensure sustainability. Compared to the aviation fuel currently used in commercial aircraft, SAF can reduce CO2 emissions by up to 80%. Therefore, it will contribute markedly to reducing greenhouse gas emissions. As such, the development and use of SAF will play a pivotal role for the aviation industry to achieve the global environmental goal of Net Zero 2050, or zero carbon emissions by year 2050.

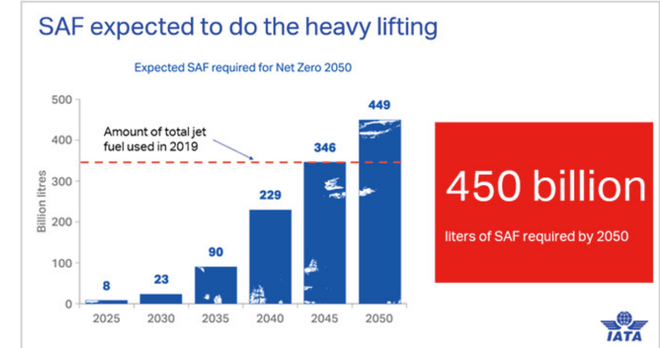
Generating a considerably lower amount of carbon emissions than the generally used aviation fuel, SAF is currently produced using renewable fuel resources from a variety of materials including waste oil and fat, urban wastes, and nonfood crops. SAF can also be used together with the existing jet fuel. In addition, it can be synthetically produced through a process of capturing carbon directly from the air. However, there are a number of factors that impede the commercialization of SAF, such as high production cost, limited supply volume, uncertainty of regulations, and insufficient public awareness and acceptance. Some of these factors are discussed in detail below.

- Availability: Currently, SAF is produced only in some regions, with the production volume limited as well. Therefore, in the current stage, the production cannot meet the global demand for jet fuel. According to an analysis by the International Air Transport Association (IATA), SAF consumption stood at a mere 0.05% of overall jet fuel consumption in 2020 and increased by only 0.1% until 2022.
- Price: With the production cost still high and economy of scale not achieved, the price of SAF is considerably higher than that of the existing jet fuel. Although the price difference between SAF and existing fossil fuels varies depending on the materials and technologies used, SAF is roughly three to four times more expensive.
- Certification: To use SAF in commercial air transport, strict technological and safety standards must be met. Certifications for use by related organizations such as ICAO, EASA, and ASTM International are also required. The certification process is time-consuming and complicated as it requires tests for a number of stakeholders. This can impose a burden on the new SAF market entrants and hinder innovative solution development.
- Policy: A supporting policy framework is necessary to expedite and promote the development and use of SAF. The policy framework may include incentives, statutes, regulations, standards, carbon pricing mechanism, etc. However, the policy environment concerning SAF differs by region and country, and such inconsistency causes uncertainty and complexity in the aviation industry. In addition, some policies can lead to unintended outcomes or conflicts, such as affecting food security, biodiversity, or social equity.

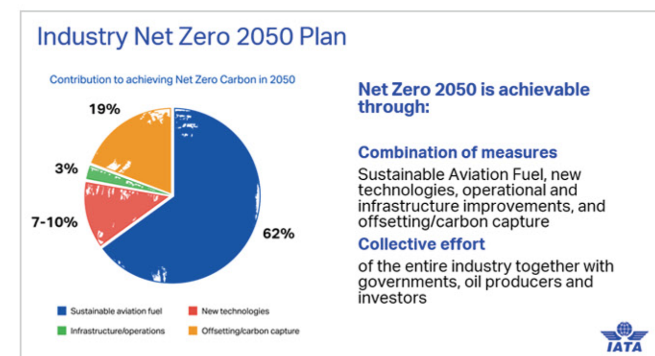
Despite such issues, IATA is dedicating its best effort to global SAF roadmap development, establishment of a global coalition for SAF, development of a global SAF certification system, SAF policy framework support, etc. in order to recommend and promote the development and use of SAF, which is essential for the future of the aviation industry. IATA also provides various guidelines and methodologies such as the IATA SAF Guide, IATA SAF Handbook, and IATA SAF Calculator to help airlines adopt SAF for their aircraft operation.

In fact, advanced airline companies already recognize the importance of SAF, and they are actively promoting the SAF introduction. For example, KLM Royal Dutch Airlines has been leading the use of SAF in Europe since a long time ago; Airbus and Boeing, the two leading aircraft manufacturers, are researching aircraft engine development, etc. for greater compatibility with SAF. In some countries such as Norway, the law requires including SAF by a certain percentage in the aviation fuel sale. These policies play an important role in promoting the use of SAF across the aviation industry.

In Korea, Korean Air announced a plan to introduce SAF in 2023, and the government is strengthening support for SAF-related R&D and infrastructure development. Aside from making an important contribution to the attainment of the international environmental goal, this movement expedites the aviation industry's transition to a sustainable future.

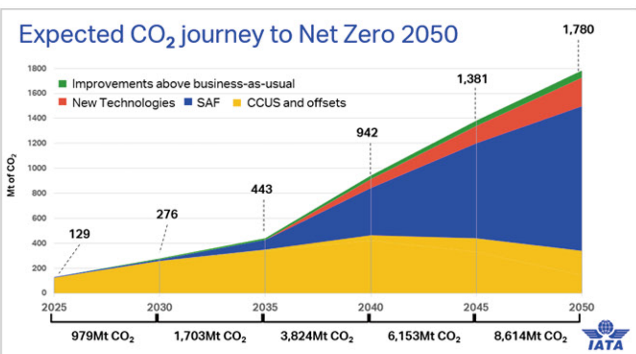


According to the IATA Economic data, SAF production volume as of 2022 is 0.25Mtd, which is a mere 0.1% of the aviation fuel produced around the world. Although this is approximately one million liters, the amount falls considerably short of the massive fuel demand of the aviation industry. However, SAF production volume is expected to increase each year. In 2023, total SAF production volume was 0.5Mt, which was almost double that of 2022. The expected SAF production volume in 2024 is 1.5Mt, or approximately three times that of 2023. By 2050 as the target year for Net Zero in the aviation field, approximately 450 billion liters is expected to be required per year. As illustrated by the graph, an extremely small amount of SAF is produced and used at the moment. However, the volume is predicted to increase rapidly after 2035. The amount of jet fuel used around the world in 2019–which is before the COVID-19 outbreak–was approximately 340 billion liters. Since SAF alone is forecast to exceed this figure considerably by 2050, the aviation industry can be expected to continue developing in the future. In addition, a considerable amount of aviation fuel demand will be met with SAF.



IATA is proposing a number of strategic plans to achieve the Net Zero goal of the aviation industry. Along with efficient aircraft operation, infrastructure and operation improvement, technological innovation, carbon offset/capture, etc., SAF is the most important component, emphasized as a core element for the reduction of carbon emissions in the aviation industry.

According to the IATA data, SAF development and use are expected to make the largest contribution–approximately 62-65%–to the achievement of Net Zero 2050. This figure was calculated as technological innovation–which includes high output engine development, aircraft design development to minimize air resistance, and method of increasing fuel efficiency–infrastructure development and effective aircraft operation, and carbon offset/capture generally practiced in other industrial sectors are expected to contribute to the goal attainment by approximately 7–10%, 3%, and 19%, respectively. Therefore, SAF development and use are very important, and this is seen to play a critical role in the future of the aviation industry. As illustrated by this graph, the aviation industry must take such measures harmoniously in order to achieve the goal of Net Zero 2050. Likewise, for the goal attainment, joint effort across industrial sectors including the government, oil producers, and investors is required.



This graph shows the estimated carbon emissions from the aviation field from 2025 to 2050. Without any intervention, the emission amount will increase continuously. Through the harmonious application of new technologies, SAF development and use, and carbon capture, utilization, and storage (CCUS) and carbon offset measures, however, the aviation industry will successfully achieve Net Zero by 2050.

To meet the demand for SAF, which will play such critical role, the production volume needs to be increased drastically. To this end, government policies are very important. The governments of each country must develop policies and reach an international agreement to encourage the expansion of the SAF production scale, and diversify the SAF supply materials for access at not only the departure points but also the destinations according to the characteristics of aircraft operation. In particular, to narrow the cost gap between SAF and the currently used aviation fuels, IATA supports the policies of each government to provide incentives to SAF producers and users through subsidies, tax deductions, pricing, public procurement, etc. Considering the circumstances where sufficient preparations have not been made, strict and forced sanctions would serve as a negative factor for the healthy development of the aviation industry.

Another task concerning the use of SAF is insufficient public awareness and acceptance of SAF as an alternative to the existing jet fuel. IATA recognizes that public awareness and consumer preference are important factors affecting SAF demand promotion and policy support for SAF production and use. Therefore, IATA will dedicate greater effort to providing information and education on the advantages and potentials of SAF to the public in order to reduce CO2 emissions from the aviation field, and strengthen its sustainable development.

SAF Accounting Policy and Benefits

SAF Accounting Policy aims to ensure effective processing of the complicated SAF accounting. This refers to a method of tracking and controlling the entire process from SAF production to use. The most widely used technique is chain-of-custody (COD). In a complicated supply chain where SAF is used together with the existing aviation fuel, a methodology and a system for effective management are particularly required. These are important factors to guarantee the sustainability and environmental advantages of SAF, and help airlines effectively achieve their carbon reduction goals. COD includes the following elements:

- Material Tracking: To track the entire process of transport from the source of a material to the end product
- Production Process Monitoring: To record accurately and monitor each stage of the production process
- Quality Control: To investigate if the product quality meets the prescribed criteria
- Certification and Labeling: To label if a product meets specific criteria or certification requirements
- Documentation and Reporting: To document the relevant data and processes, and report the details to related authorities and stakeholders

The systematic approach and processing method guarantee the sustainability of SAF and provide reliability for consumers and regulatory organizations.

Issues of SAF Introduction and Countermeasures for Airports

To meet the increasing SAF demand, airports are required to undergo an extensive improvement of their logistics and storage facilities. The expected scale of global infrastructure investment by 2035 is approximately USD 5 billion; this means that airports need to promote the transformation of their key bases for SAF supply. In addition, for SAF accounting by airports, the following must be taken into consideration:

- Supply Chain Management: Airports must pay attention to the successful management of SAF supply, storage, and use. By doing so, a foundation for efficient SAF management and tracking can be secured.
- Accurate Recording of Mixing and Storage Process: The mixing ratios between SAF and existing aviation fuel as well as the storage processes must be accurately recorded so that the amounts of SAF use by each airline can be tracked.
- Documentation of Environmental Benefits: The environmental benefits of SAF use–such as carbon reduction–must be documented and shared with airlines and related regulatory organizations.
- Regulatory Compliance and Transparent Reporting: The requirements of environmental regulations must be met, and SAF-related activities must be transparently reported. This is an important role of airports in achieving the sustainability goal of the aviation industry.

CAAF/3 Result

At the Third Conference on Aviation Alternative Fuels (CAAF/3) hosted by the International Civil Aviation Organization (ICAO) in 2023, the attendees agreed on a global framework to promote SAF production in all regions for fuel consumption in international aviation in order to achieve a 5% reduction in carbon emissions by 2030. To reach this level, SAF production of approximately 17.5 billion liters (14Mt) is required.

The entire amount of SAF produced so far has been purchased and consumed, so it did not cause any demand issues. In fact, in 2023, the cost of SAF purchase by the aviation industry–which recorded the largest fuel cost in history–was approximately USD 756 million. In addition, 43 airlines have already entered into contracts to use approximately 13 million tons of SAF by 2030, and a large number of additional contracts are being concluded. However, securing supply to meet the demand remains a task to be addressed. More than 63 million tons of SAF are expected to be produced in 2029. The government must develop policies to encourage SAF production and support airlines in using SAF without any problems in supply.

The introduction and spread of SAF play an important role in increasing the sustainability of the aviation industry and responding to climate change issues. This implies that it is a task that will require global-level cooperation and policy-wise efforts beyond simple technological advancement. Through innovative approaches such as the use of SAF, the future of the aviation industry will become more sustainable and environment-friendly. IATA will continue promoting and assisting in the change and contribute to the aviation industry's development through cooperation with airlines and airports. AIR

Sustainable Aviation Fuel and Roles of Incheon International Airport in Climate Crisis Response

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[Climate Crisis Response and Sustainable Aviation Fuel]

In July last year, United Nations Secretary-General António Guterres officially declared, "The era of global warming has ended; the era of global boiling has arrived." The severity of issues caused by climate change has intensified that it even threatens the survival of humankind. In January this year, the Copernicus Climate Change Service (C3S)-a climate change monitoring organization of the European Union-reported that 2023 was the warmest year since the official monitoring was started, and that it may be the starting point for the earth to enter the phase of "global boiling" beyond "global warming." In addition, according to the World Meteorological Organization (WMO), a specialized agency of the United nations, the probability of the average global temperature being higher by 1.5℃ or more than that in the pre-Industrialization era (1850-1900) within the next five years is as high as 66%.

In 2018, the Intergovernmental Panel on Climate Change (IPCC)-the United Nations body for assessing the climate change-related global risk and preparing countermeasures across the globe-adopted the Special Report on Global Warming of 1.5℃ to promote agreement and joint action among gov-

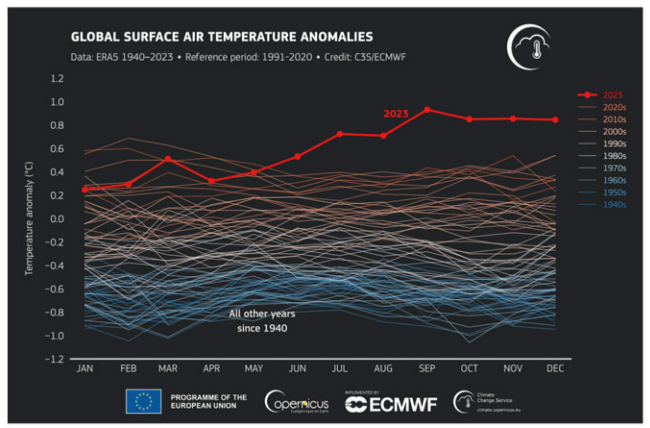


Fig. 1 Annual Average Global Surface Air Temperature Changes

Source: https://climate.copernicus.eu/weve-lost-19-years-battle-against-global-warming-paris-agreement

ernments around the world for greenhouse gas (GHG) reduction and transition to Net Zero society and, at the same time, urge enterprises and society to fulfill their responsibilities and carry out response activities to achieve Net Zero.

According to the United Nations Framework Convention on Climate Change and Kyoto Protocol, the International Civil Aviation Organization (ICAO) is promoting a policy for GHG reduction in the international aviation field[1]. At the 37th ICAO Assembly in 2010, it declared 2% annual fuel efficiency improvement and Net Zero growth after 2020 as the GHG reduction objectives for the international aviation field. Then, cognizant of the limitations in aircraft operation optimization technologies such as manufacturing of aircraft with low fuel consumption, development of shortened routes, and air traffic flow control, ICAO finalized the implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) as a market-based action at the 39th Assembly in 2016.

According to the implementation of CORSIA, all airlines operating international routes are required to purchase offset credits for the amount of reductions in other fields or submit the performance of sustainable aviation fuel (SAF) use in relation to the increasing amount of GHG emissions since 2020. While ICAO member states can participate in the CORSIA implementation voluntarily until 2026, the participation becomes mandatory for all member states from 2027.

This paper is aimed at examining SAF as a means of reducing greenhouse gas (GHG) emissions in detail, including the related roles of Incheon International Airport.

1) The Decisions of the Third Conference of the Parties (COP-3) to the United Nations Framework Convention on Climate Change (FCCC) in 1997 (Kyoto Protocol) prescribed regulation of the reduction of greenhouse gas (GHG) emissions from transport between countries by specialized organizations (ICAO and IMO designated for international air transport and international marine transport, respectively), not by individual countries (Kyoto Protocol 2.2). In addition, with the target of the Paris Climate Agreement in 2015 limited to the strengthening of reduction objectives by individual countries, the promotion of GHG reduction policy for the international aviation field is currently handled by ICAO.

[General Aviation Fuel and Alternative Aviation Fuel]

To consider fuel as a means for GHG reduction, it is necessary to learn about aviation fuels. Aircraft are powered by fuel. The fuel used for aircraft is called aviation fuel. As fuel used to power jet engine or internal combustion engine, aviation fuel is also called jet fuel or AV-GAS.

Aviation fuel, just like land transport fuels, is produced and provided by a number of oil companies and suppliers. It is supplied to various aircraft models through the jet fuel system established in airports. The fuel that can be used in aircraft without any adjustment of the aircraft, engine fuel system, or fuel distribution network is called drop-in fuel. In other words, as aviation fuel is produced and provided by various oil companies and suppliers, all fuels must be drop-in fuel.

Meanwhile, conventional aviation fuel (CAF) based on the crude oil stored underground emits GHG-the cause of climate change-across the entire process from production to use. Therefore, it causes an increase in the concentration of GHG in the air. The fuel that generates less GHG than CAF is called alternative aviation fuel (AAF).

According to the materials used in its production, AAF is categorized into drop-in fuel or non-drop-in fuel depending on whether the existing system for aviation fuel supply and use can be utilized without adjustments. As a non-drop-in fuel, AAF-just like hydrogen and natural gas-generates less GHG than the conventional aviation fuel. However, it requires the development of a new aircraft model equipped with a turbine or an engine to which the fuel can be applied, including establishment of fuel production and supply facilities. For example, to use hydrogen fuel, a hydrogen turbine or a hydrogen engine that can be powered by hydrogen and a system for hydrogen supply, storage, and distribution are required. In other words, to use non-drop-in fuel, not only a stable supply chain for the fuel but also infrastructure for the fuel supply must be established first. In addition, using this type of fuel incurs very high cost and requires advanced technologies. This paper focuses on alternative fuel as drop-in fuel.

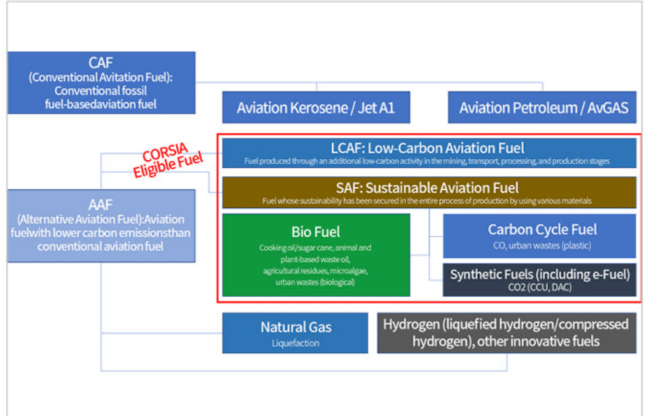


Fig. 2 Definitions and Types of Aviation Fuel and Alternative Fuel

Source: Can Lower Carbon Aviation Fuels (LCAF) Really Complement Sustainable Aviation Fuel (SAF) Towards EU Aviation Decarbonization?, https://doi.org/10.3390/en14196430 reconstructed by the author

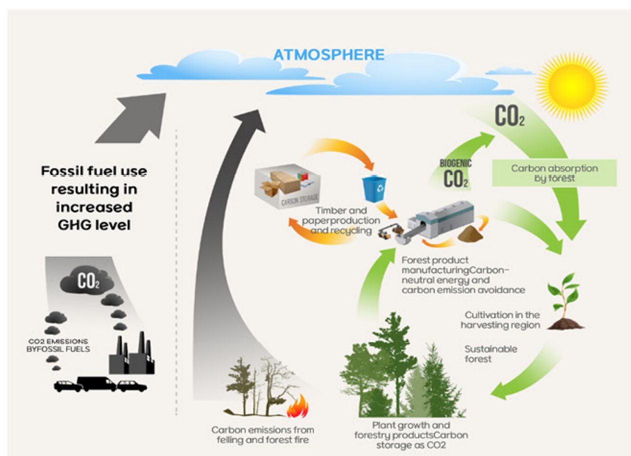
To adapt the conventional aviation fuel system to AAF, the drop-in fuel concept is applied. In other words, it must be possible to use AAF without altering the equipment, facilities, and aircraft using conventional aviation fuel. To this end, the fuel quality must meet the requirements of conventional fuel. According to the definition of alternative fuel-"fuel that may be used as a substitute for petroleum products without changing the fundamental structure of the equipment for burning petroleum products"-in the Petroleum and Alternative Fuel Business Act of Korea, the concept of drop-in fuel is a prerequisite for alternative fuel.

For aviation fuel quality control, Incheon International Airport receives fuel that meets the quality criteria for compliance by oil companies and strictly and continuously controls the quality through a number of stages according to the international standards for aviation fuel control, such as inspections for fuel incoming and outgoing to and from storage and fueling facilities in the airport.

[What is Sustainable Aviation Fuel?]

SAF is defined as fuel that generates less GHG than CAF across the entire process from crude oil mining to final use. Therefore, a plan to reduce GHG emissions such as capture CO2 to offset crude oil mining[2] or use renewable energy in the process of crude oil refining or transport can be applied to SAF even if it is made using the same material (fossil fuel) as that of general aviation fuel. This is called low-carbon aviation fuel (LCAF). LCAF is a CORSIA-eligible fuel (CEF) for which at least 10% GHG reduction of conventional aviation fuel is recognized as a GHG reduction performance by CORSIA. Considering the cost and technologies required for renewable energy, etc. that need to be introduced to the CCS or crude oil refining process, however, considerable time and technological development will be necessary until commercialization.

As a type of CEF, sustainable aviation fuel (SAF) refers to aviation fuel produced using materials other than fossil fuel. In general, the materials that can be used in the alternative fuel production are biodegradable materials (biomass) such as cooking oil, sugar cane, and agricultural and forestry residues.



Biomass-based CO2 circulation through carbon cycle→ No increase in GHG emissions into the air

Fig. 3 Concept of Carbon Cycle and Biomass

2) Carbon Capture and Storage (CCS): This refers to a series of processes and technologies to capture carbon dioxide existing in the atmosphere or which is generated through stacks when fossil fuel is burned, compress and transport the captured carbon dioxide, and store it safely in onshore or offshore underground repositories. As the key technologies of CCS are similar to those of petroleum development, major oil companies and related companies across the world are leading the CCS business.

Carbon generated from industrial processes or fossil fuel use can also be used (carbon cycle fuel). According to the principle of global carbon cycle, i.e., carbon used in biomass production is regenerated from CO2 in the air through photosynthesis, GHG generated from biomass burning is considered not to increase the CO2 concentration in the air.

Although carbon cycle fuel is produced using carbon generated from fossil fuel, recycling carbon from the fossil fuel exhausted (waste) is not considered a cause of increased GHG emissions.

ICAO largely divides the materials for SAF production into four types. Primary and co-products-the first type-are the main products of a production process whose purpose is production itself. These products have significant economic value and elastic supply. For these products, there is a causal relationship between the price of the material and production quantity. Energy crops such as jatropha, silver grass and switch grass, and byproducts such as molasses belong to this category. The second type is byproducts. These are secondary products with inelastic supply and economic value. Examples include palm fatty acid distillate generated from the process of palm oil refining, and technical corn oil (TCO) generated from the process of ethanol production. The third type is wastes, which are materials without elastic supply or economic value. Waste is any substance or object that the holder discards or intends to or needs to discard. Raw materials or substances that have been modified intentionally or contaminated are not covered by this definition. Examples include waste cooking oil, urban wastes, and waste gas generated from industrial processes. The fourth type is residues. These are secondary materials with inelastic supply and little economic value. Examples are tree barks, husks, stems, straw, etc.

As a critical point for SAF production, sustainability must be ensured throughout the production process from securing materials to producing aviation fuel. ICAO have very strict sustainability assessment criteria for SAF. While only the GHG reduction effect of SAF (to produce a GHG reduction effect of at least 10% in comparison to conventional aviation fuel) and its impact on carbon storage (to minimize the destruction of carbon storage with large biological carbon storage capacity) were assessed in the category of carbon reduction until last year, ICAO will conduct the assessment under 14 subjects beginning this year including those in the environmental impact category (continuity of GHG reduction, water quality and resources, soil, and air preservation, wastes and chemicals, impact of earthquake and vibration (applicable to LCAF only)) and socioeconomic category (human rights and labor rights, right to use land and land use, right to use water resources, regional and social development, food security). Currently, sustainability assessment on SAF is conducted through two organizations[3] designated by ICAO. The GHG reduction performance of CORSIA cannot be used without the sustainability certification. The SAF sustainability certification was first obtained by ECOCHEM (China), Neste (Netherlands), and WorldEnergy (US) in June 2023.

In addition to sustainability assessment, SAF must meet the aviation fuel quality criteria to become a CORSIA-eligible fuel. In particular, SAF is produced using various materials and through a number of physical and chemical processes and must be a drop-in fuel with complete and perfect quality as aviation fuel. As the aviation fuel standard and quality requirement, the aviation fuel-related standard of ASTM International[4] is most widely applied. It is also referred to as a quality certification standard in various reports of ICAO.

For SAF to be used, it must meet the three requirements below as specified by ASTM International. First, it must be assessed as aviation fuel according to the ASTM D4054 standard. When certified as fuel for use in aircraft, it then needs to obtain certification for the maximum mixing ratio with conven-

3) ISCC (International Sustainability & Carbon Certification) and RSB (Roundtable on Sustainable Biomaterials), designated through application with ICAO in 2020

4) As a private international standardization organization established based on the American Society for Testing and Materials, ASTM International develops and publishes specifications of various products including jet fuel. The D1655 standards for aviation turbine fuel were first published in 1959 and have been continuously modified based on changes in the engine and aircraft overhaul, with new material-related quality requirements reflected.

tional aviation fuel and quality according to the ASTM D7566 standard. Lastly, to be used as aviation fuel, the mixed aviation fuel is required to obtain ASTM D1655 certification.

Table 1 Order of ASTM Standard Acquisition for Aviation Fuel and SAF and Details of SAF Use

Category	Standard	Description
ASTM D4054[5]	Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives	As a standard for new aviation fuel and additive registrations, it consists of a stage for the aviation fuel physical property test (phase 1 - tiers 1 and 2) and a stage for the performance test (phase 2 - tiers 3 and 4).
ASTM D7566[6]	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons	This is an accompanying document defining the characteristics of and requirements for synthetic mixing components that can be mixed with the conventional CAF. Certification is issued for fuel that meets the standard so that it can be used in the existing supply system.
ASTM D1655	Standard Specification for Aviation Turbine Fuels	As the most generally used international standard, it prescribes the requirements for conventional jet fuel.

As of June 2023, ASTM D7566 and ASTM D1655 announced standards for 11 SAF production processes, materials, and maximum mixing criteria. Five standards are being reviewed additionally[7].

While ASTM D4054, D7566, and D1655 are the standards for aviation fuel quality, JIG standard deals with aviation fuel handling[8]. To reflect the latest trends of aviation fuel quality control practice, JIG continuously updates the aviation fuel handling standard. Approximately 2,750 airports around the world including Incheon International Airport are being regulated. Inspectors designated by JIG regularly check and inspect the standard implementation status in airports. JIG carries out aviation fuel handling management in the airport by using the Aviation Fuel Quality Requirements for Jointly Operated Systems (AFQRJOS), a checklist that includes the requirements of ASTM D1655. With respect to SAF, tracking of synthetic fuel (SAF) was first mentioned in Bulletin 96[9] published by JIG. In other words, the status of certification in relation to the type and mixing ratio of SAF must be checked as specified by ASTM D7566, including information on SAF production for the tracking management of the SAF content in aviation fuel.

As alternative fuel to the conventional aviation fuel, SAF is not only a prominent means for GHG reduction but also maintains the same performance and quality as those of conventional aviation fuel, contributes to sustainability, and at the same time guarantees safe aircraft operation through strict quality and performance control.

[Sustainable Aviation Fuel Policy and Demand Trends]

As the most promising GHG reduction measure in the international aviation industry, sustainable aviation fuel is being produced using various materials. According to the ICAO website, as of January 2024, SAF supply is available at 108 airports around the world, 289 production plants have been or are to be established, and 78 million tons of SAF can be produced per year. Because stable material supply and sufficient production facilities have not been secured and the production process is complicated, however, the price of SAF is at least three times higher than that of the conventional aviation fuel, which serves as the biggest hindrance to the activation of SAF use. To address the issue, ICAO and a number of countries are proposing policy-wise directions.

At the 41st ICAO Assembly in 2022, the long-term aspiration goal (LTAG) to achieve Net Zero by 2050 in the international aviation field was declared, and the required rate of SAF's contribution to GHG reduction was estimated at up to 81%[10]. To this end, ICAO requested the member states for policy development to spread the use of SAF and LCAF. At the 3rd ICAO Conference on Aviation and Alternative Fuels (CAAF/3)-the largest SAF-related conference organized by ICAO-held in November 2023, ICAO's vision for SAF and LCAF by 2050 was reviewed. The participants also resolved to achieve a 5% reduction of GHG emissions by 2030 through the use of SAF and LCAF.

As a country with the largest aviation industry, the US announced in September 2022 the SAF Grand Challenge, which is a plan to secure SAF supply and demand. Under the final goal of achieving complete conversion of aviation fuel into SAF within the country by 2050, the US developed a roadmap to produce 35 billion barrels of SAF each year until 2050 based on a mid- to long-term goal of 3 billion barrels of SAF production each year until 2030. In addition, it established a policy to promote the supply and use of SAF by assigning individual roles to each government department, such as support for the expansion of SAF development and production to the Department of Energy, SAF inspection, certification, and consumption promotion to the Department of Transportation, securing and commercialization of SAF materials to the Ministry of Agriculture, and environmental assessment or deregulation to the Environmental Protection Agency.

The European Union started SAF policy development at an earlier phase. As part of the Fit for 55[11] announced by the European Commission in July 2021, ReFuel EU Aviation obligated fuel suppliers to mix in SAF at the ratio of at least 6% and 70% by 2030 and 2050, respectively. In particular, ReFuel EU Aviation aims to supply carbon cycle fuel-based SAF-which is e-FUEL-by year in addition to the bio fuel-based SAF. In Europe, Norway, Sweden, and France have implemented the supplier obligation to mix in SAF by 0.5% since 2020, 0.8% since 2021, and at least 1.0% since 2022, respectively. From 2025 when the obligation set forth by ReFuel EU Aviation is applied, the countries are expected to follow the EU criteria.

Japan declared Net Zero for the international aviation field in 2022; in May 2023, it declared SAF supply accounting for 10% of the aviation fuel supplied in the country (1.7 million kl per year). In addition, the UK government set a goal of using 10% of SAF by 2030.

As for private airlines, Air France-KLM (AFR-KLM), Delta Air Lines (DAL), Qantas (QAN), Qatar Airways (QTR), and Singapore Airlines (SIA) set detailed goals for SAF use, such as 50% by 2030, 50% by 2035, 10% by 2030, 10% by 2030, and 5% by 2030, respectively. The number of airlines declaring quantitative goals is gradually increasing.

The First Mover Coalition was launched at the World Economic Forum in 2021 as a consortium of companies developing the early market for innovative clean technologies in relation to the areas of large-scale GHG emissions using their purchasing power. Currently, it consists of approximately 90 members across the world.[12] The First Mover Coalition established detailed GHG reduction objectives for seven sectors including aviation. The goal of airlines and air operators is to use at least 5% of SAF by 2030, and the GHG reduction effect

5) D4054-22, ASTM International, Jul. 2022
6) D7566-22, ASTM International Aug. 2022
7) https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx, access on Jan. 18, 2024 identified
8) JIG (Joint Inspection Group) was established in the 1970s by major oil companies providing services to key airports around the world (Air BP, Exxon Mobil, Chevron, Q8 aviation, ENI, Total, Shell) with the goal of developing a series of standards for jet fuel operation and handling in the airport facilities.
9) Aviation Fuel Quality Requirements Product Specifications Bulletin 96, Oct. 2016
10) https://www.icao.int/environmental-protection/LTAG/Documents/Summary%20of%20LTAG %20information%20on%20fuels.pdf
11) Legislation bill package to achieve a 55% reduction of GHG emissions in Europe compared to 1990 by 2030
12) https://initiatives.weforum.org/first-movers-coalition/home, access on Jan. 18, 2024 identified

of the SAF used must be 85% or more of that produced by the conventional aviation fuel. Airline users (those that purchase the services by paying charges) will cooperate with air operators that use at least 5% of SAF by 2030, and the SAF used must also have a GHG reduction effect of 85% of that of the conventional aviation fuel. The 28 participating companies are direct aviation industry stakeholders that include aircraft manufacturers such as Airbus and Boeing, airlines such as Delta Air Lines, Lufthansa Group, Qatar Airways, and United Airlines, and freight transport companies such as DHL and FedEx.

Some overseas airports provide direct financial incentives including subsidies for SAF purchase and deduction of passenger service charges in order to compensate airlines for their SAF purchasing costs. The airports providing these incentives include Heathrow Airport of the UK, Schiphol Airport of the Netherlands, Brussels Airport of Belgium, and San Francisco Airport of the US, and the number of such airports is gradually increasing. In addition, carbon reductions achieved by airlines through voluntary use of SAF can be purchased by users, which can then declare it as their contribution to carbon reduction through corporate activities.

As discussed so far, the effort to promote SAF demand in the international aviation field spans not only international organizations and governments of each country but also private airlines and aviation service users. This is considered to be attributable to the increased demand for SAF in the private sector as corporate climate crisis response activities including ESG activities and mandatory climate disclosures—which have become an issue as of late—are being emphasized. As an example, while announcing sustainability disclosure criteria for listed companies, the International Sustainability Standards Board under the International Financial Reporting Standards Foundation specified that businesses must include GHG emissions and climate crisis response scenario in their disclosure information from 2025, and additionally disclose Scope 3 emissions—which have indirect and social impact—from 2026. Scope 3 emissions include GHG emissions from logistics (aviation) services used by businesses, so businesses must opt for logistics (aviation) services with less GHG emissions. Incheon International Airport must consider promoting the use of SAF for the reduction of GHG emissions from airlines that use the airport because the GHG emissions of airlines contribute to the Scope 3 emissions of the airport.

[Sustainable Aviation Fuel and the Roles of Incheon International Airport Corporation]

In May last year, a bill to suspend the operation of air routes whose distance is equivalent to that for 2.5 hours of train travel officially took effect in France. Although it was significantly eased from the decision of the Citizens' Convention for Climate in 2019 to ban the operation of routes that can be covered through train travel by less than four hours, this is an example of GHG emissions resulting in an actual restriction of a transportation means that the aviation industry must take note of in particular. According to this bill, France closed down the Paris to Nantes, Lyon, and Bordeaux routes.

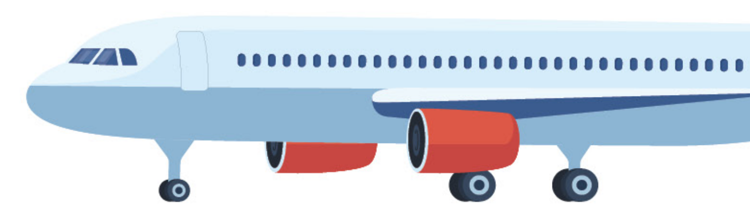
In September last year, SAF was first used in an aircraft departing from Korea. Compared to the cases in overseas airports, this was a belated but very important experience. Most of all, the oil company went through a procedure for importing and supplying SAF, and the airport experienced using the fueling facility. The government and testing agency also secured the basic data necessary in establishing the quality criteria and legal grounds for the use of SAF in Korea.

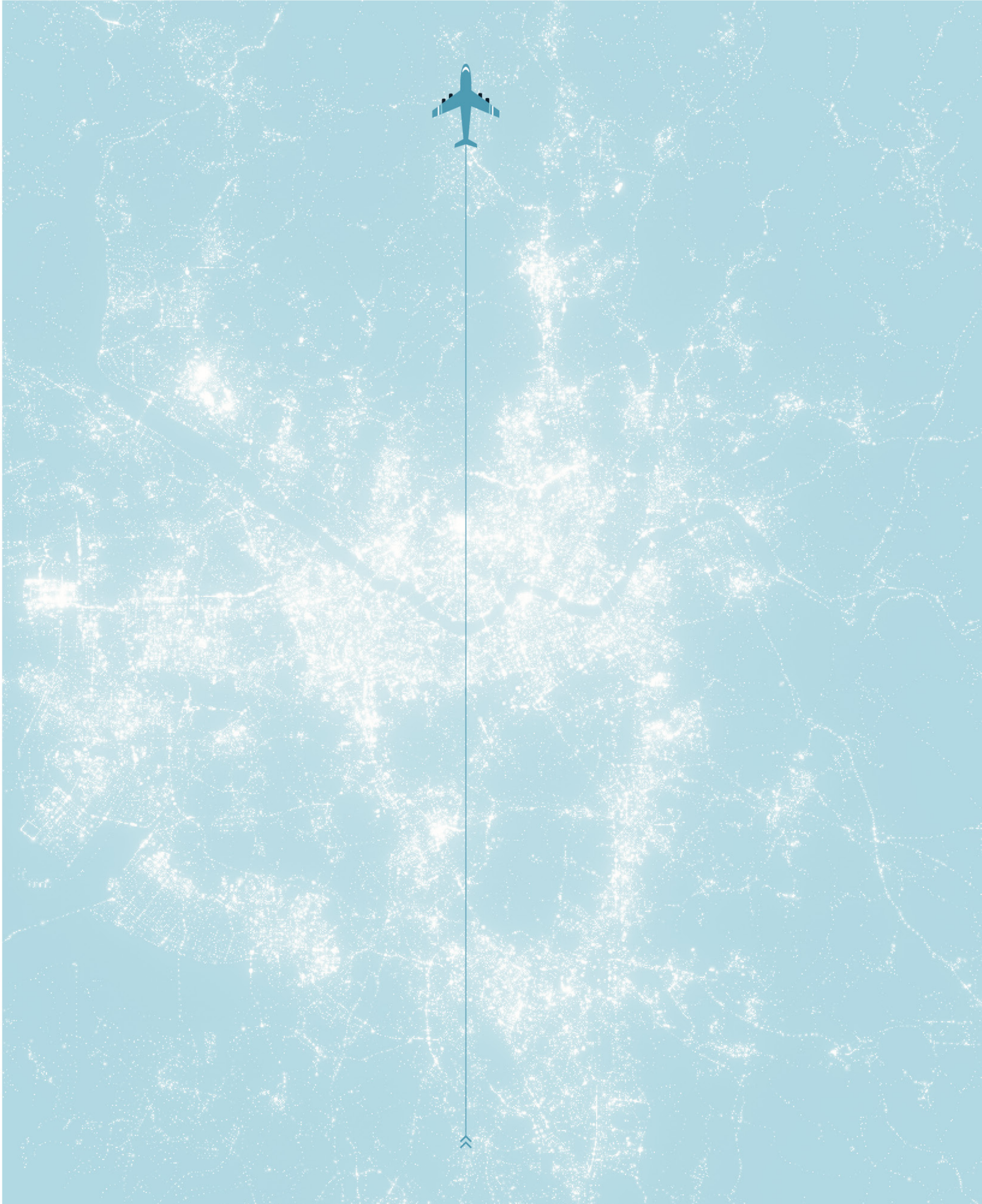
Fig. 4 **Incheon International Airport Commencing the Operation Verification Project Using SAF**

As a drop-in fuel, SAF does not need changing or specifying the facilities for use within an airport. As SAF is supplied to and stored in airports by being mixed with the conventional aviation fuel, however, it cannot be identified as to how much of it was physically supplied for a specific route or to a specific airline. To check the fueling performance of an airline or the supply amount by an oil company, it may be necessary to check and monitor not only the details of the supply agreement between the airline and the oil company but also the amounts of SAF received into and released from an airport. Currently, Incheon International Airport records the types and ratios of SAF received according to the JIG standard checklist. Therefore, it will be possible to secure monitoring information on the amounts of SAF received into and released from the airport.

Meanwhile, a large number of overseas airlines are actively setting goals for SAF and entering into a long-term agreement with suppliers. In addition, although limited, the number of airports financially supporting airlines using SAF is gradually increasing. Incheon International Airport plans to complete stage 4 of the construction project this year and estimates the passenger handling capacity to be at least one hundred million. For Korean flag carriers, system or policy-wise support will be possible. With regard to using airports in Korea, however, overseas airlines will take into consideration the status of SAF supply, SAF supply price, and additional incentives in comparison to those of the airports in neighboring countries such as Japan and China; hence the need for a plan to secure related competitiveness.

The use of SAF incurs additional expenses. Technically, the SAF production cost cannot be lowered to that for the conventional aviation fuel. In other words, consumers will need to bear an additional cost burden to use the aviation services that pursue the practice of GHG reduction. Even so, the expenses cannot be fully passed on to consumers. In addition to airlines, oil companies manufacturing fossil fuel-based petroleum products also need to make efforts for securing SAF□which produces a high carbon reduction effect□at competitive prices and using it for not only climate crisis response but their survival as well. In this regard, as the number of passengers for air transport approaches one hundred million, Incheon International Airport must play the role of a bridge to provide financial support to airlines and oil companies for their continuous and efficient effort for SAF, and promote the spread of SAF.





AITRI FOCUS

Impact of SAF Introduction on the Aviation Industry: Focusing on Airline Management[1)]

Senior Researcher Seok Kim
Airport Industry Technology Research Institute

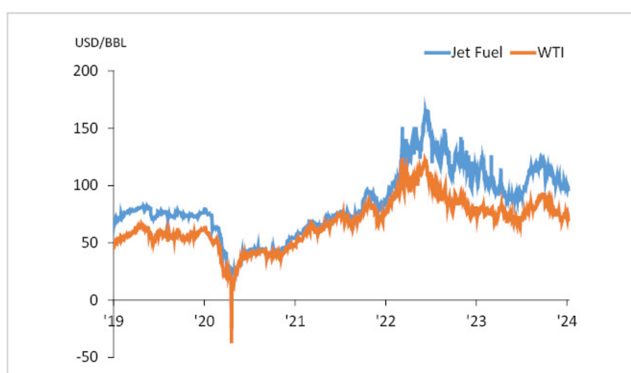
The International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) are implementing the Net Zero roadmap for the aviation industry, and the EU is required to increase the percentage of sustainable aviation fuel (SAF) use to as much as 85% by 2050. However, the SAF price is three to five times higher than that of the conventional aviation fuel, so it is expected to have a significant impact on the aviation industry. In this study, the impact of fuel cost, etc. on the financial performance of airlines was analyzed using data from 20 major global airlines (full service carriers (FSCs) and low-cost carriers (LCCs)), and the key results are presented below.

As the analysis found that the financial performance of airlines-such as operating profit margin-is significantly affected by variable costs including fuel cost, airlines are bound by macroeconomic variables such as oil price in the short term and requirement of Net Zero such as SAF use in the long term. In addition, cost competitiveness is expected to serve as a critical element for the survival of an airline company.

Airlines are introducing aircraft models of high efficiency in order to reduce carbon emissions and ease the burden of fuel cost. For the time being, however, mixed use of old and new models is expected. In addition, large aircraft models such as A380 will most likely be decommissioned, with aircraft operation centering on mid- to large-scale aircraft models such as B787-9/10 and small aircraft models such as A321-neo and B737-8.

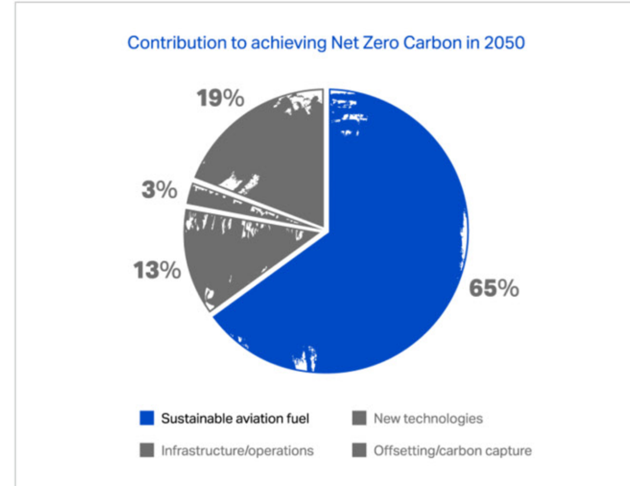
Introduction

Oil price is a major factor affecting passenger fare. Airlines are continuously striving to reduce fuel cost–which accounts for a large portion of their operating cost–by introducing equipment (aircraft) with high fuel efficiency, etc. With the Net Zero issues further intensifying and the era of SAF starting, however, fuel cost is expected to continue wielding a significant impact on the aviation industry.



International Oil Price Trend Source: Bloomberg

1) The content of this study was prepared by modifying and supplementing the data of the Korea Corporation Management Association presented in November 2023 and is the personal opinion of the author.



Estimated Contribution of the Aviation Field to Net Zero Source: IATA

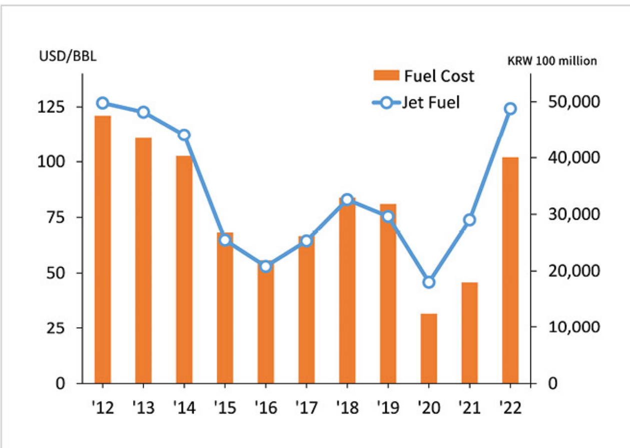
The International Civil Aviation Organization (ICAO) is piloting CORSIA[2)] to suppress the increase of carbon emissions from the aviation field (since 2021), and the International Air Transport Association (IATA) declared Net Zero 2050 at the General Assembly in 2021. In addition, under the policy of mandatory use of SAF, the EU needs to replace 2% of total fuel consumption for aircraft landing in EU nations with SAF by 2025. As a result, airline companies are facing the issue of high fuel cost.

The Era of SAF Alternative Fuel Source: YTN Science

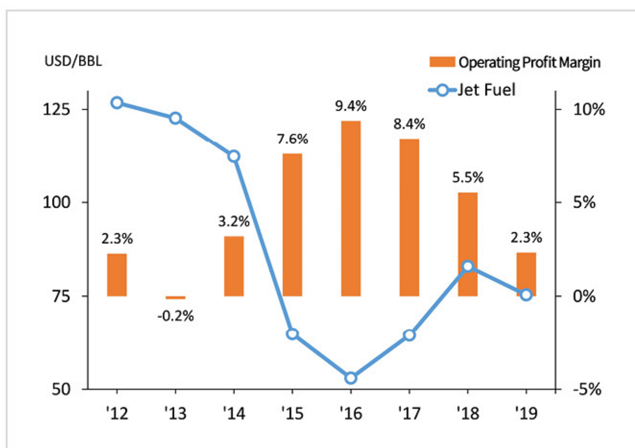
2) CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation): A scheme to control international aviation carbon emissions at the 2019 level with approx. 110 countries voluntarily participating (mandatory participation from 2027)

Relationship Between Oil Price and Airline Operating Expenses (KE)

The fuel cost of an airline fluctuates in the same pattern as that for the aviation fuel price. Therefore, high oil price imposes a cost burden on the airline. Fuel cost accounts for approximately 30% of the operating expenses. With the revenue amount not significantly changed from that of ordinary times, the changed fuel cost affects the company's operating expenses. As a result, the operating profit margin tends to decrease when aviation fuel price is high.



Trend of KE Fuel Cost Source: Bloomberg, DART of Financial Supervisory Service



Trend of KE Operating Profit Margin

Source: Bloomberg, DART of Financial Supervisory Service

Analysis of Fuel Cost Impact Using Data from Major Global Airlines

Hypothesis: Does fuel cost a major factor that commonly affects the financial performance of airlines across the world?

The data used in the empirical analysis are those of 20 major global airlines including Korean Air–Korea's flag carrier–from 2014 to 2022. The data were secured through Bloomberg Terminal, and the following is the list of major global airlines used in the analysis:

Airlines Subject to Analysis

Airline	Country	IATA Code	No. of Aircraft Owned	Revenue (USD million)
Korean Air	Republic of Korea	KE	169	10,316
Delta Air Lines	US	DL	1,340	47,007
Singapore Airlines	Singapore	SQ	196	11,650
Lufthansa	Germany	LF	763	40,776
Air France	France	AF	554	30,438
Emirates	UAE	EK	270	24,774
All Nippon Airways	Japan	NH	303	18,160
Cathay Pacific	Hong Kong	CX	236	13,653
Air China	China	CA	699	19,718
Qantas	Australia	QF	314	9,573
Jeju Air	Republic of Korea	7C	45	1,181
T'way Air	Republic of Korea	TW	28	696
Jin Air	Republic of Korea	LJ	26	781
Southwest Airlines	US	WN	747	22,428
JetBlue Airways	US	B6	259	8,094
Spirit Airlines	US	NK	145	3,831
Ryanair	Ireland	FR	466	9,440
easyJet	UK	U2	342	3,837
Norwegian Air Shuttle	Norway	DY	156	4,949
Air Asia	Malaysia	AK	246	2,863

* Number of aircraft owned and revenue based on fiscal year 2019

Source: Bloomberg

The variables used in the analysis[3] are from the management data of airlines such as: revenue, which is the sales amount; OPM, or operating profit margin; NPM, or net profit margin; fuel, which is fuel cost; RPK, or revenue passenger kilometer; aircraft, which is the number of aircraft owned; GDP, which is GDP per capita; fare, which is airfare based on the urban wage and salary of workers from the United States Consumer Price Index (CPI); and COVID, which is a dummy variable during the pandemic period.

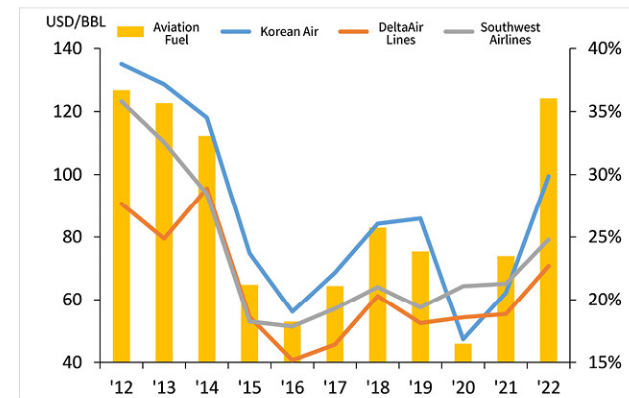
Empirical analysis was performed using statistical program R on panel data. For details on the panel data analysis methodology using R, refer to the study by Park Beom-jo (2012)[4].

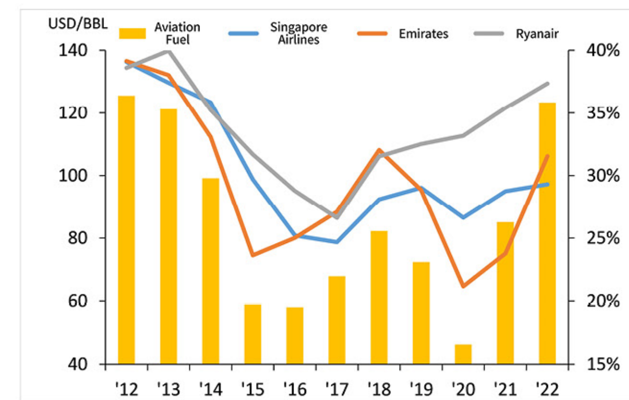
To identify the impact of fuel cost on the financial performance of airlines, Rev_Fuel–which was calculated by dividing fuel cost by revenue–was used as the key variable. The reason fuel cost (fuel) variable was not directly used is that higher fuel cost is related to higher sales. Likewise, the aim is to avoid multicollinearity with other independent variables. The Rev_Fuel variable is the ratio of cost to sales. Therefore, it can be used as an analysis indicator for cost per KRW 1 of sales. In addition, it is considered valid for identifying the impact on business performance caused by fluctuations in the cost of fuel, which is a type of management resource.

```
>    mydata1[c(1:9),]
   Airline   FY   Revenue    OPM     NPM     Fuel    RPK  Aircraft      GDP    Fare  Covid
1       KE 2014  11097.65 0.0319 -0.0176  3830.28  67948       148 28100.01  303.66      0
2       KE 2015   9998.14 0.0760 -0.0361  2370.16  71647       161 28737.44  289.68      0
3       KE 2016   9919.26 0.0938 -0.0514  1888.62  75908       160 29467.12  280.70      0
4       KE 2017  10443.68 0.0810  0.0769  2314.98  77843       161 30312.89  275.19      0
5       KE 2018  11498.22 0.0552 -0.0065  2996.43  80189       166 31059.27  267.09      0
6       KE 2019  10316.05 0.0170 -0.0473  2732.49  83273       169 31645.95  268.08      0
7       KE 2020   6287.26 0.0322 -0.0263  1059.09  19079       159 31378.16  219.07      1
8       KE 2021   7648.53 0.1673  0.0730  1572.79   8634       154 32786.69  219.99      1
9       KE 2022  10411.01 0.2150  0.1327  3110.67  31621       155 33719.39  285.12      1
```

Example of Panel Analysis Data

Before proceeding with the analysis, the relationship between aviation fuel price and Rev_Fuel variable by airline was examined using a graph. As shown in the figure below, the fuel cost to sales of airlines changed in the same pattern as that for the aviation fuel price fluctuations. Therefore, using the Rev_Fuel variable, the impact of fuel cost on the financial performance of airlines can be intuitively identified.





Aviation Fuel Price by Year and Fuel Cost to Revenue Ratio by Airline[5]

Source: Bloomberg

3) The unit for revenue and fuel cost is USD million. RPK (revenue passenger kilometer) is an indicator for the passenger transport performance of an airline and is calculated by multiplying the number of paid passengers by transport distance. 1 RPK means the transport of one paid passenger by 1km. As for GDP, it is the real GDP per capital of a country where the airline belongs and is fixed at the amount in USD as of 2010. For airfare, as collection of data by airline is limited, the data in the United States Consumer Price Index (CPI) were used as proxy.

4) Park Beom-jo, Panel data analysis using R: Application to automobile gasoline consumption volume panel models of OECD states, Industrial Study, No. 1 Vol. 36, 2012, pp.83-100

5) The settlement period of Korean Air, Delta Air Lines, and Southwest Airlines on the left is December, and that of Singapore Airlines, Emirates, and Ryanair on the right is March. Therefore, aviation fuel price was also calculated by year according to the settlement period.

Presented below are the results of estimation with pooling model, fixed effect model, and random effect model for regression model in the panel analysis model to analyze OPM (operating profit margin) with dependent variables.

Although the results can be roughly estimated using the pooling model, they were verified using the plm package of R software in order to identify the existence of fixing or random effects for the analysis data. As a result, F-test statistical value was found to be 18.551, indicating that a fixing effect exists in the panel data at 1% significance level. In addition, to verify the random effect, LM test statistical value and Hausman test statistical value were estimated. As a result, the existence of random effect in the panel data was identified at 5% significance level, and the fixed effect model was verified to be more valid than the random effect model.[6]

	Pooling Model				Fixed Effect Model				Random Effect Model			
Coeffcient	*Estimates*	*S.E.*	*Stat*	*p*	*Estimates*	*S.E.*	*Stat*	*p*	*Estimates*	*S.E.*	*Stat*	*p*
(Intercept)	-8.22	1.06	-7.77	**<0.001**					-8.26	1.06	-7.78	**<0.001**
Rev Fuel	-1.37	0.24	-5.63	**<0.001**	-1.97	0.31	-6.45	**<0.001**	-1.59	0.26	-6.12	**<0.001**
RPK [log]	0.17	0.03	5.19	**<0.001**	0.20	0.04	5.23	**<0.001**	0.19	0.03	5.48	**<0.001**
Aircraft [log]	-0.15	0.04	-4.11	**<0.001**	-0.33	0.09	-3.51	**0.001**	-0.17	0.04	-4.36	**<0.001**
GDP [log]	0.01	0.03	0.19	0.849	0.50	0.26	1.97	0.051	0.00	0.04	0.00	0.997
Fare [log]	1.32	0.19	6.91	**<0.001**	1.33	0.21	6.36	**<0.001**	1.34	0.19	7.11	**<0.001**
Covid	0.02	0.05	0.33	0.743	0.04	0.05	0.84	0.404	0.04	0.05	0.82	0.415
Observations	180				180				180			
R^2 / R^2 adjusted	0.632 / 0.619				0.685 / 0.633				0.649 / 0.637			

Panel Analysis: Dependent Variable – OPM (Operating Profit Margin)

The empirical analysis result indicated that the impact of fuel cost on the operating profit margin of airlines has very high statistical significance.7) In other words, as fuel cost increased, operating profit margin decreased. The increase of operating profit margin according to an increase in RPK and airfare appears to be an intuitively valid result. However, the decrease of operating profit margin of an airline when the number of aircraft owned by the airline is larger is estimated to be attributable to the impact of high fixed cost along with the effect of variable cost such as fuel cost. Meanwhile, the GDP and dummy variables during the pandemic period were found to have no significance.

6) Due to the restriction in the number of pages of the contribution, the verification result was not entered in detail. The data can be requested from the author.

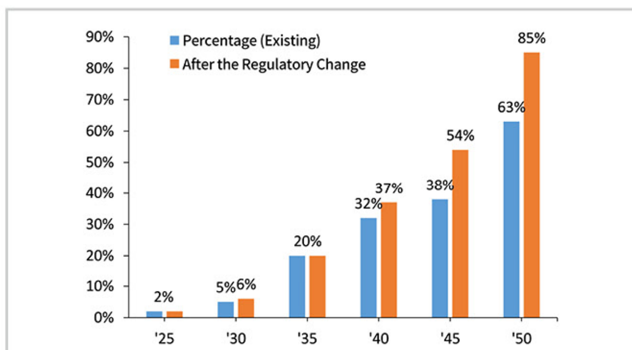
7) The same result was produced through an analysis using NPM (net profit margin) as the dependent variable.

The analysis result–which is for fuel cost to affect the operating profits of airlines significantly–indicates that airlines are bound by macroeconomic variables such as oil price in the short term and requirement of Net Zero such as SAF use in the long term. In addition, cost competitiveness is expected to serve as a critical element for the survival of an airline company. The price of SAF is known to be three–five times higher than that of aviation fuel. As a result, 2% and 10% mixing of SAF increases the fuel cost by 4–8% and 20–40%, respectively.

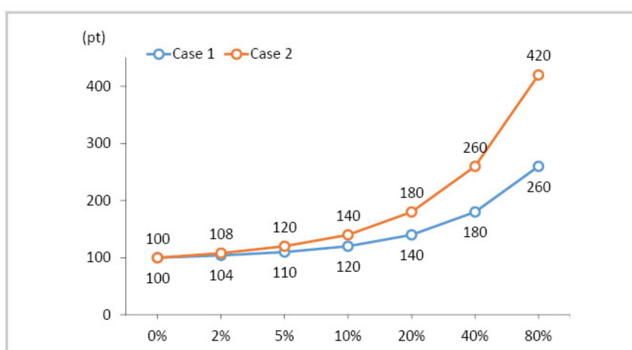
Response of Airlines to High Alternative Fuel (SAF) Cost, and its Impact

SAF is used as a method for responding to Net Zero, which is expected to wield a significant impact on the aviation industry, but incurs high cost. In Europe, while the rate of mandatory SAF use will increase from 2% (2025) to 85% (2050), the price of SAF–which is three–five times higher than that of the conventional aviation fuel–is expected to amplify the fuel cost burden on airlines.

Airlines will expedite the introduction of new aircraft models to



Percentage of Mandatory SAF Use in Europe Source: EU

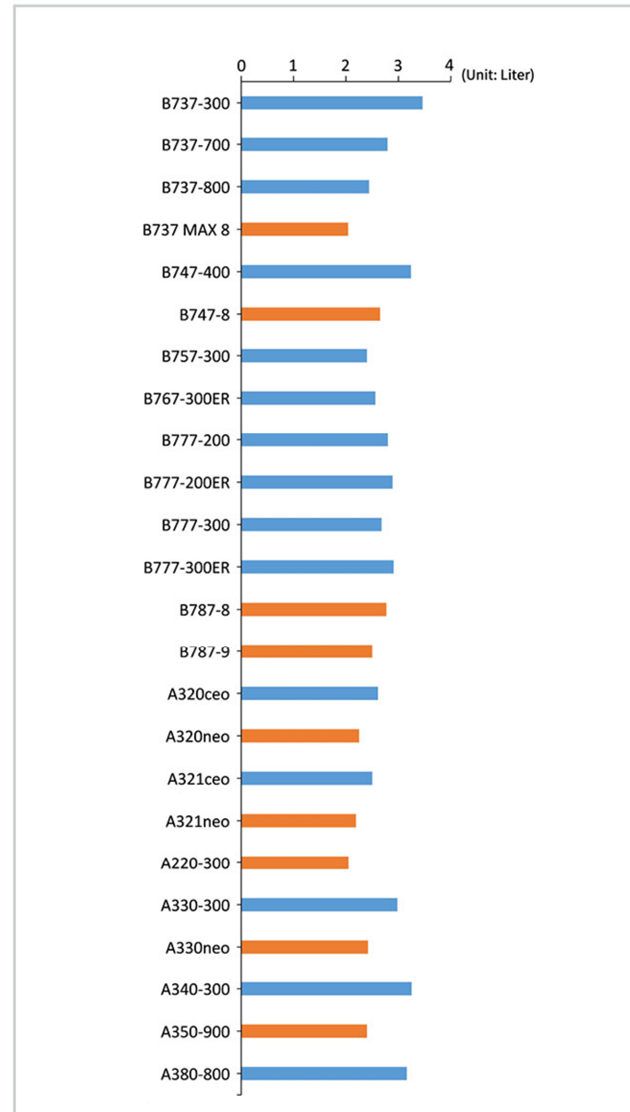


Changes in Fuel Cost by Percentage of SAF

* SAF price, assuming to be three–five times higher than that of the existing aviation fuel

reduce carbon emissions and lower the cost elements such as fuel cost. However, as it is not easy to change all aircraft in a short period of time, mixed use of the old and new models is expected for the time being. Moreover, considering fuel efficiency, eco-friendliness, etc., large aircraft models such as A380 will most likely be decommissioned, with aircraft operation centering on mid- to large-scale aircraft models such as B787-9/10 and small aircraft models such as A321-neo. Compared to the old models, however, the newly introduced models have a smaller number of seats. This, in the long term, is expected to result in the reduction of the number of passenger seats for mid-to long-distance routes.

In fact, as shown in the figure below, the high fuel efficiency



Fuel Consumption per Seat by Aircraft Model (per 100km)

Source: Okinawa Airportairport

of the new models is also seen in the aircraft models of similar families (i.e., B737 MAX 8 fuel consumption reduced by 16.4% in comparison to B737-800).

B787 and A321-neo models with high fuel efficiency are smaller in size than the existing aircraft and are therefore expected to have an impact as well in terms of airport operation. As one aircraft-regardless of the size-is assigned for each of air traffic control, mooring, and gate use, airport operation will also be affected by the aircraft model and route-related strategies of airlines. In addition, due to the fuel cost,[8] etc., which is expected to increase according to the use of SAF, the passenger fare (air ticket price) may not be restored to the past level. In fact, increased passenger fare will result in a decrease in consumer benefits.

8) As an example, the increased fuel cost is being passed on to consumers in the form of fuel surcharge.

Example of Impact of SAF Based on Changes in Operating Profit and Expenses of KE

Assuming that the mixing percentage of SAF as alternative fuel is 2%, Korean Air's operating expenses in 2019 increase from KRW 12,005.3 billion to KRW 12,132.6–12,260 billion, and operating profit decreases by KRW 127.3 billion–KRW 254.7 billion. As such, when SAF is used together with the existing aviation fuel, fuel cost increases considerably, e.g., by 4–8% in case of 2% SAF mixing and by 20–40% in case of 10% SAF mixing.

Based on the performance in 2019, 5% SAF mixing alone causes Korean Air's financial performance to be in the red by recording an operating loss.

Changes in Operating Profit and Expenses of KEin 2019 According to the Percentage of SAF

(Unit: KRW 100 million)

Revenue	Oper-ating Expens-es (Fuel Cost)	Per cen tage of SAF	Operating Expenses (Fuel Cost)		Operating Profit	
			Case1	Case2	Case1	Case2
122,917	120,053 (31,832)	0%	120,053 (31,832)		2,864	
		2%	121,326 (33,105)	122,600 (34,379)	1,591 △1,273	317 △2,547
		5%	123,236 (35,015)	126,419 (38,198)	-319 △3,183	-3,502 △6,366
		10%	126,419 (38,198)	132,786 (44,565)	-3,502 △6,366	-9,869 △12,733
		20%	132,786 (44,565)	145,519 (57,298)	-9,869 △12,733	-22,602 △25,466

* Based on the data of KE in 2019, Case 1 (2) assuming that the price is three (five) times that of existing aviation fuel

Limitations of Research

In this study, an empirical analysis was performed using data from 20 global airlines. Due to the insufficiency of data on LCCs, however, the data of Jeju Air, T'way Air, and Jin Air–the Korean LCCs–were included. Nevertheless, the revenue, number of aircraft owned, etc. of the three airlines are remarkably different from those of other global airlines. Moreover, in terms of the analysis period, data from 2023–which was a period of recovery from the pandemic–could not be included. Any remaining typographical errors are the mistakes of the author. AIR