WHITE PAPER

Sustainable Aviation Fuel and Existing Infrastructure

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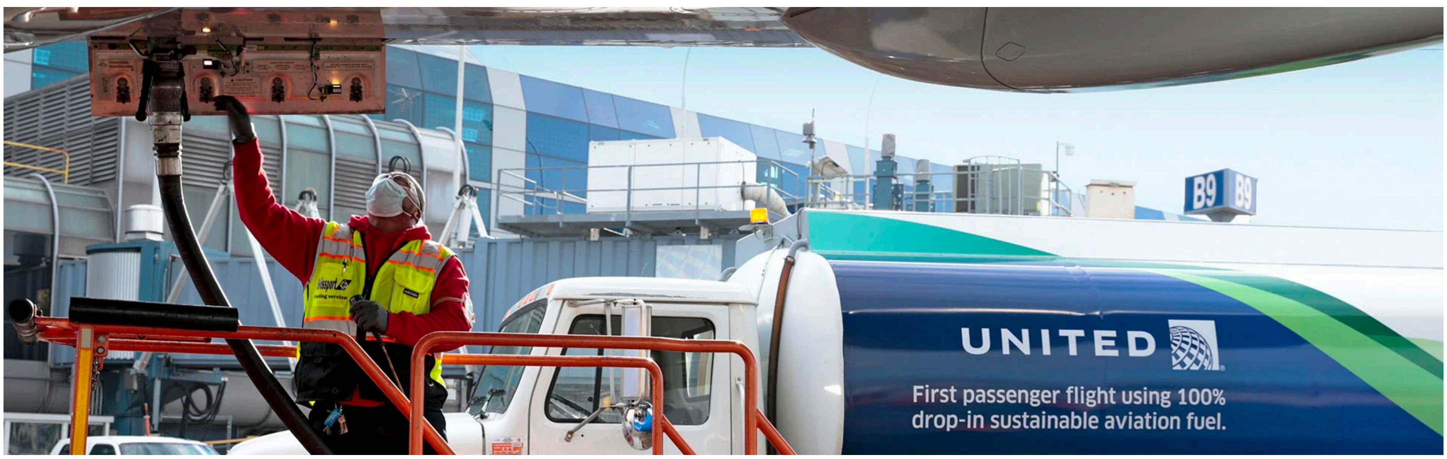
As the aviation industry explores sustainable alternatives to Jet A or Jet A1 grade kerosene fuel, sustainable fuel is emerging as a potential substitute. Even though it is considered a simple drop-in fuel, airports may need to upgrade fueling systems.



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Across the aviation industry, sustainable aviation fuel (SAF) is an emerging topic of interest, but current adoption is minimal. Officials working for airlines and airports are searching for sustainable alternatives to crude oil, and SAF could be a promising solution. Scalability and cost are the primary challenges facing the industry. A major cost consideration is existing infrastructure. Understanding whether current infrastructure can be used for SAF without requiring significant modification is essential to making SAF a viable fuel for airlines.

Demand for Air Travel, Conventional Fuel and Alternative Fuels

In 2019, U.S. airlines alone used 18.4 billion gallons of jet fuel. Based on the Federal Aviation Administration's (FAA) projected air traffic growth for the next decade, 30 billion gallons of jet fuel will be used annually by 2030. Today, most jets are powered by Jet A or Jet A1 aviation grade kerosene fuel. SAF, electric and hydrogen are the three alternative fuel sources the industry is exploring. Each of these alternative fuels has a significantly different feasibility timeline based on technical barriers, with infrastructure playing an outsized role.

Industry Standards for SAF

Within the aviation industry, and corroborated by the International Air Transport Association (IATA), SAF is the principal title to describe non-conventional aviation fuel. SAF is produced from alternative, non-petroleum feedstocks, which may include farm residues, plant or cooking oils, biogas or municipal waste. These feedstocks are processed and refined into hydrocarbon jet fuel components.

Unlike other synthetically derived biofuels of the past, the jet fuel components produced through SAF processes are chemically identical to their conventional jet fuel counterparts. For use in commercial jets, a neat (100% pure) SAF blend component is first tested using stringent criteria before blending with conventional jet fuel.

Currently, the SAF blend components can be combined at concentrations up to 50% of the blended jet fuel end product, depending on which SAF feedstock technology was used (IATA, 2020). The blended SAF jet fuel is tested again to confirm it meets the specified property requirements for jet fuel. The performance properties and specific technical requirements for both the SAF blend components and blended SAF jet fuel are specified in the American Society for Testing Materials (ASTM) standard D7566, "Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons." This newly written ASTM standard is a more stringent version of the long-standing, internationally recognized Jet A/A-1 fuel standard, ASTM D1655, "Standard Specification for Aviation Turbine Fuels." ASTM D7566 includes specific annexes, or supplemental mandatory information, for each type of approved SAF blending component.

Clearing the Air on SAF

As enthusiasm grows for greener methods to power jets and airplanes, some aviation professionals are noting potential challenges associated with the operational integration of SAF with existing infrastructure and technology. Discussions among experienced professionals working in government and regulatory agencies can clarify what is factual and what remains unknown about SAF. This is especially true when discussions include input from industry and academic research.

SAF Is a Drop-In Fuel

The performance and characteristics of blended SAF and conventional jet fuel are essentially identical because they contain the same concentrations of the same hydrocarbon jet fuel components. However, petroleum-derived fuels typically contain more trace materials, such as sulfur or nitrogen compounds. Many of the SAF blend components need to be blended with conventional jet fuel because they lack the aromatic hydrocarbons that are naturally found in petroleum-derived jet fuel. Aromatics help to swell seals and gaskets and, historically, they have been considered beneficial when selecting sealing materials.

Most SAF feedstock processes lack the necessary level of aromatics. However, there are undesirable aspects of aromatics, such as having lower specific energy and contributing to combustor liner wear. Furthermore, aromatics are difficult to burn, and incomplete combustion of the aromatics emits troublesome particulates into the atmosphere. This is known as "sooting." SAF blended with conventional jet fuel keeps aromatic content maintained at a specified level, preserving seals in existing aircraft and infrastructure, while minimizing the undesirable effects.

After neat SAF is blended with conventional jet fuel, it is tested in accordance with ASTM D7566, which requires a minimum of 8% aromatics. Since the blended fuel is essentially chemically identical to conventional jet fuel — including aromatics — the D7566 standard contains a provision allowing redesignation from ASTM D7566 jet fuel batches to ASTM D1655 (Frontiers in Energy Research, 2021). The blended fuel can be handled, stored and dispensed just like conventional Jet A/A-1 and is therefore considered a drop-in fuel.

It is important to note current SAF usage is low, and SAF blend percentages are limited. To date, the common view is that existing airport fueling systems and infrastructure can, without modification, readily use SAF as a drop-in fuel. In the future, as SAF usage rises or if neat SAF is no longer required to blend with conventional jet fuel, additional periodic analysis on infrastructure implications will be needed to confirm seal compatibility, seal shrinkage and more.

SAF Is Not Exactly Like Jet A Fuel

Although put to the same use once produced, Jet A/A-1 fuel and SAF differ most obviously in their origins, and most notably in their life cycle of greenhouse gas emissions. With neat SAF, up to 80% less carbon dioxide (CO2) life cycle emissions occur when compared to conventional jet fuel (IATA, 2019). The remaining 20% accounts for discharges due to the energy inputs of growing, transporting and refining SAF. Although burning SAF still generates the same amount of CO2 as conventional jet fuel, this is offset by the CO2 absorbed or reclaimed by the feedstock itself. Impurities like sulfur and particulate matter releases are less common in the production and use of SAF relative to conventional jet fuel (IATA, 2020).

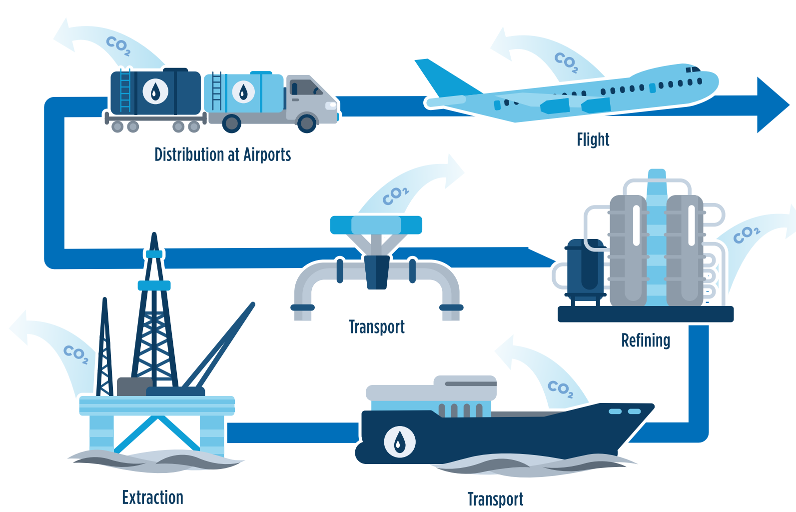

Figure 1: Carbon Life Cycle Diagram for Fossil Fuel

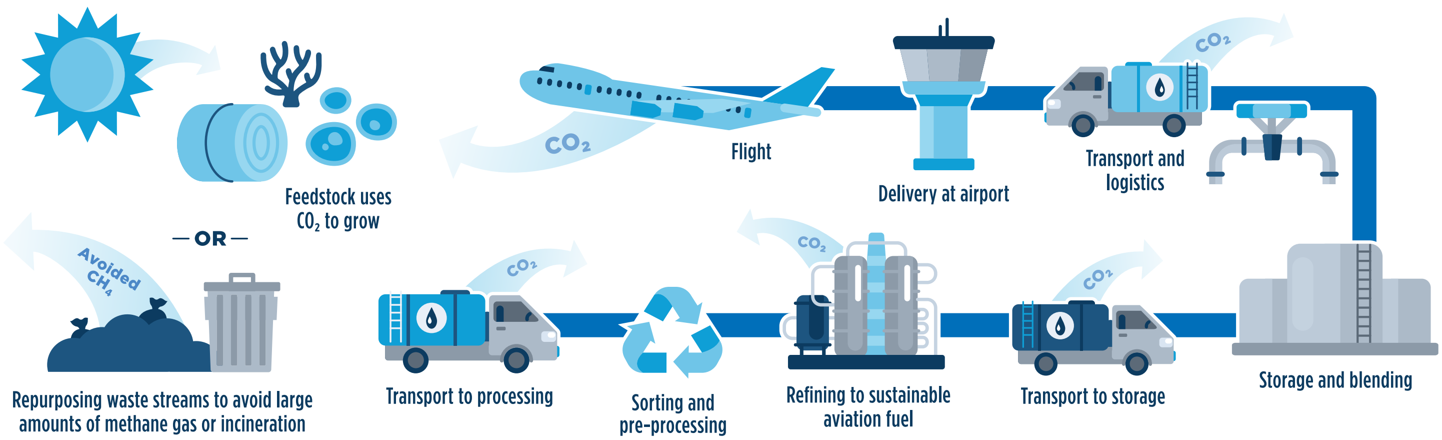

Figure 2: *Carbon Life Cycle Diagram for SAF*

Total energy cost is another point of comparison. Producing petroleum-derived hydrocarbons currently remains the more cost-efficient option. Supply lines for petroleum-derived fuels are well-established, which reduces energy use for transporting and distributing raw and refined products. Environmental impacts of SAF vary greatly depending on feedstock components. Some sources, like municipal waste and used cooking oils, add even more value as they would otherwise go unused — taking up space in a landfill and possibly emitting additional greenhouse gases.

It should also be noted that while SAF has undergone vigorous materials testing, much of that relates specifically to metallic and seal materials commonly found in aircraft and fuel infrastructure. However, it is still relatively unknown how different SAF feedstock blends may interact with impurities — such as dirt, dust and sludge — that can accumulate in fuel systems. From a chemical standpoint there should not be any differences. At this point in SAF technology, it is essential to engage a trusted fuel system engineering team to fully evaluate existing infrastructure before making the transition to SAF. The engineer can also monitor the system once the use of SAF is implemented.

Not All SAF Is the Same

Currently, there are several different feedstock pathways to produce SAF that are specified under ASTM D7566 annexes, with technical requirements for each feedstock. As this technology develops and new feedstock pathways are discovered, refined and tested for safety and performance, they will be added as annexes to this standard. While each specified feedstock technology produces jet fuel hydrocarbon chains, some will not yield a fully formulated fuel. As previously mentioned, some feedstocks will produce a fuel lacking in aromatics or other jet fuel components and be considered a compositional subset of jet fuel. SAF produced from these feedstocks must be blended with other feedstock products and conventional jet fuel to meet the safety and performance requirements of ASTM D7566 and be considered a fully formulated fuel.

Alternatively, there are some SAF feedstocks that will produce a fully formulated fuel complete with aromatics and without need for blending with conventional jet fuel. These SAF feedstock pathways are at the forefront of testing since they are the likely future candidates for approval as a drop-in fuel while also comprising 100% SAF. However, these feedstock processes currently remain limited to a maximum 50% blend as a conservative approach to entry into service (Frontiers in Energy Research, 2021).

SAF in Practice

Looking at the aviation fuel market, more than 99% is conventional jet fuel; less than 1% is SAF already blended with conventional fuels (IATA 2019). The U.S. government and three collaborating agencies introduced the U.S. Sustainable Aviation Fuel Grand Challenge, which aims to increase production of SAF from approximately 180 million gallons per year at current levels to 3 billion gallons per year by 2030. This would be more than a 16-fold increase in production, presenting some unique challenges. If this aggressive goal is met by 2030, SAF would replace about 10% of conventional jet fuel sources necessary for meeting anticipated demand.

There are examples of SAF implementation all over the world, including in the United States. A couple of national cases provide insight into the complexities and opportunities of SAF fuel introductions into the mainstream.

Los Angeles International Airport — Truck Delivery

In 2016, United Airlines was the first to receive SAF at Los Angeles International Airport (LAX) and to treat it as a regular function of operations. World Energy delivers this product by truck to LAXFUEL, a consortium of airlines working together at LAX to comprehensively manage fuel supply and airport activities directly servicing aircraft. The LAXFUEL fuel facility is equipped with one truck unloading position that has a dedicated filtration system and is primarily used to accept preblended SAF.

As of now, LAXFUEL has not witnessed any unusual conditions with the filtration system. Blended SAF is transferred into the next tank designated for receipt, just like a conventional jet fuel would be. Operationally, no changes were made for SAF distribution. LAXFUEL averages receiving nearly 800,000 gallons of SAF blends per month, with the blends then distributed to all participating carriers.

San Francisco International Airport — Pipeline Delivery

In 2017, San Francisco International Airport (SFO) started organizing airlines and fuel producers to expand SAF adoption in San Francisco, throughout California and beyond. Convening several SAF-focused coalitions to address specific challenges for this industry, the group's objective is to increase SAF use at SFO to 5% of jet fuel by 2025. To reach this benchmark at SFO, the SAF group first identified strategies to increase supply, which was no small feat.

SAF suppliers at SFO are Neste and World Energy. The neat, or unblended, SAF from Neste is shipped by sea to NuStar's Selby Terminal in the San Francisco Bay Area, where it is blended and certified to meet ASTM D7566/D1655 requirements. About twice a month, batches of 630,000 to 1,890,000 gallons are sent to SFO through an existing Kinder Morgan pipeline.

Today, SFO receives the highest SAF volume in the world, with multiple airline partnerships. SFO is helping to lead the way for SAF when it comes to aviation collaboration and best practices. SFO members co-chair international groups organizing to increase SAF use throughout the world.

Conclusion

SAF is already, at least in small quantities, becoming a simple drop-in fuel at a few major airports. Although the U.S. SAF Grand Challenge to produce 3 billion gallons of SAF per year may be lofty, and success remains unclear, there is evidence the shift is happening today, along with a bevy of policies that encourage fuller participation in this emerging market. Now is an important time to engage with the topic of SAF and deliver a new path forward for the aviation industry.

When it comes to infrastructure, whether that is creating new blending facilities or utilizing existing fuel systems, aviation industry leaders should engage fuel system professionals with considerable direct experience. They can then assess existing facilities before the planned introduction of SAF, and provide ongoing monitoring of the system during initial stages of SAF implementation.

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