Business Aviation Guide

To the Use of Sustainable Alternative Jet Fuel (SAJF)

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Introduction

WHY THIS GUIDE?

In recent years, awareness has grown about the harmful effects on the atmosphere of greenhouse gas (GHG) emissions from industrial installations, power plants and surface vehicles, ocean-going vessels, and aircraft. The aviation industry leads the way in taking steps to improve its efficiency and address its impact on climate change.

Aviation — including business aviation — is a key contributor to economic growth and increased prosperity, enhancing communication, linking markets, and providing economic opportunity and good-paying jobs for millions of people. Business aviation contributes positively to the bottom line of businesses that depend on flexibility and agility to take advantage of economic opportunities regardless of where they are located. But the industry's license for continued growth is dependent on its ability to do so in a sustainable, environmentally-responsible manner. It is vital that business aviation do its part, and be seen to do its part, to mitigate its effect on climate change and improve its efficiency.

The aviation industry is, in fact, the only industry to have developed internationally-agreed carbon emission reduction standards for both aircraft and operators, but this is not enough; we must continue to improve the efficiency of our products and operations.

The good news is, we have made considerable progress. In 2009, the business aviation industry—representing the manufacturer and operator sectors—announced specific commitments regarding climate change[1]. To achieve our goals, we outlined a four-pillar strategy. These commitments and the four pillars are outlined in more detail later in this publication.

The single largest potential reduction in aviation's GHG emissions, and the key to reaching our goals, will come about through the broad adoption of sustainable alternative jet fuel (SAJF) in place of the current fossil-based jet fuel.

So, increasing the industry's uptake of SAJF is important, but it is clear—and natural—that many in the industry have questions about SAJF. This guide is thus designed to explain what SAJF is and what it is not. Our aim is to answer questions and allay any concerns that our community of operators, fixed-base operators (FBOs), owners, pilots, fuel providers, airports and others may have about the performance, safety and appropriateness of using sustainable alternative jet fuel wherever it is available.

1 https://gama.aero/news-and-events/press-releases/global-business-aviation-community-announces-commitment-on-climate-change/

SAJF is available today, but not widely. There are factors holding back the full deployment and commercialization of SAJF. However, safety and performance are not among them.

As we outline below, SAJF that has been produced to meet the requirements of ASTM D7566, and re-identified as ASTM D1655 (what we know as Jet A, or Jet A-1) has gone through a rigorous, exhaustive and resource-intensive testing program before it was approved for use in turbine aircraft. Civil aviation authorities and aviation industry stakeholders, including original equipment manufacturers (OEMs) and engine manufacturers, have put in place an exhaustive and thorough process to approve SAJF. In addition, the world's leading aviation regulatory authorities, including the Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA) and others, have issued clear guidance allowing the use of SAJF that has been re-identified as meeting ASTM D-1655 standards in turbine aircraft.

As the world's leading business aviation industry associations representing manufacturers, operators, FBOs and others, the General Aviation Manufacturers Association (GAMA), the National Air Transportation Association (NATA), the International Business Aviation Council (IBAC) and its constituents, the U.S.-based National Business Aviation Association (NBAA) and Europe-based European Business Aviation Association (EBAA) hope that this brochure answers your questions about sustainable alternative jet fuel. We also include information about contacting us and other organizations and groups directly if you need further information on these topics.

Selected aircraft OEMs, engine and APU manufacturers, as well as manufacturers of other components, participated in the testing process and that testing found that SAJF is compatible for use in their products with no modifications required, and with no need for recertification or additional validation.

Background

What is the role of sustainable alternative jet fuel in helping us meet our climate change commitments?

Sustainable Alternative Jet Fuel (SAJF): a general term used to describe the class of non-petroleum-based jet fuels (or blended components) that are being pursued by the industry to:

- **Reduce net life-cycle carbon dioxide (CO_2) emissions** from aviation operations.
- **Enhance the sustainability of aviation** by being superior to petrol-based jet fuel in environmental, social and economic aspects.
- **Enable drop-in jet fuel production** from multiple feedstocks and conversion processes, so no changes are required in aircraft or engine fuel systems, distribution infrastructure or storage facilities. As such, SAJF can be mixed interchangeably (is fungible) with existing jet fuel.

SAJF is also sometimes referred to as bio-jet, bio-kerosene, alternative jet, etc., or specifically by the several names for the conversion processes outlined in ASTM D7566. Any SAJF compliant with the requirements of ASTM D7566 is recognized as meeting the characteristics of traditional petroleum-based jet fuel approved under ASTM D1655 (see below).

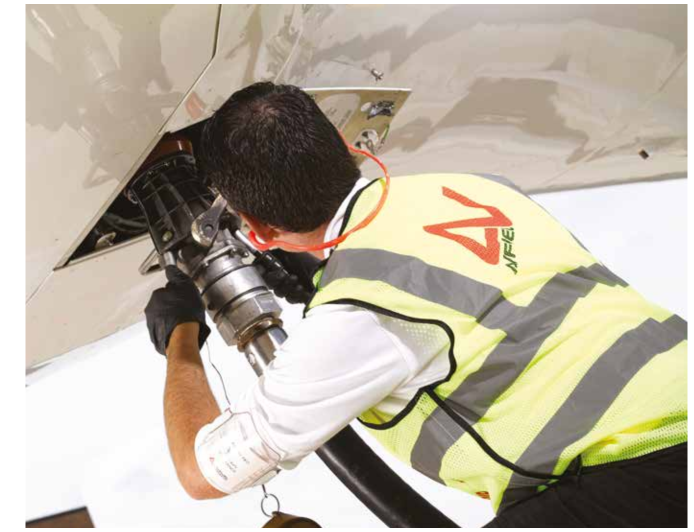
Sustainable alternative jet fuel consists of three key elements:

1. Sustainability: This is defined as something that can be continually and repeatedly resourced in a manner consistent with economic, social and environmental aims; specifically, something that conserves an ecological balance by avoiding depletion of natural resources and mitigates contribution to climate change.

2. Alternative: SAJF is non-conventional fuel[2] and may be derived from many sources whose chemical constituents can be converted to the set of pure hydrocarbons that comprise jet fuel. These substances are also processed to jet fuel in an alternative manner (via thermochemical, biochemical, and catalytic production processes). Feedstocks for SAJF are varied, ranging from cooking oil, plant oils, solid municipal waste (trash), waste gases, sugars, purpose-grown biomass and agricultural residues, among others.

3. Jet Fuel: Perhaps most importantly, SAJF, when produced to the requirements established and approved by the industry in ASTM D7566, meets the technical and certification requirements for use in turbine-powered aircraft engines and is re-identified as meeting the ASTM D1655 standard.

It is important to note that not all alternative fuel is sustainable fuel. The International Civil Aviation Organization (ICAO) has defined "aviation alternative fuel" as *"a drop-in fuel obtained from sources other than petroleum, such as coal, natural gas, biomass, and hydrogenated fats and oils. It has a potential to be sustainably produced and to generate lower carbon emissions than CAF (note: Conventional Aviation Fuel) on a life cycle basis."* [3]



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Relative to fossil fuels, sustainably-produced, unconventional jet fuel results in a net reduction in carbon dioxide (CO_2) emissions across its life-cycle. This means that even when you take into consideration the CO_2 emissions generated during the production of SAJF, from the equipment needed to grow crops, transport the raw material, refine the fuel and distribute it, the use of SAJF has been shown to provide significant reductions in overall CO_2 lifecycle emissions compared to fossil fuels. The industry has been predominantly focused on fuels that provide more than 50 percent reductions, but it is not uncommon to see approaches that deliver up to 80 percent. SAJF also contains fewer impurities, such as sulphur or complex hydrocarbons that do not burn well, like naphthalene, leading to even greater reductions in sulphur dioxide (SO_2) and particulate matter (PM) emissions.

Progress on developing sustainable fuels has been moderate (ongoing for the last decade), but is accelerating. Technical barriers to the production of SAJF have been overcome. There are now five different "pathways" approved by the aviation industry and available to producers to convert different feedstocks into jet fuel. There are several other pathways currently under review by the industry for potential inclusion in ASTM D7566. However, up to this point, there has been a lack of commercial-scale investment that would make the deployment and commercialization of SAJF a mainstream occurrence in the near term.

2 ASTM D1655 currently defines **conventional fuel** in Paragraph 6.1.1 as: Aviation turbine fuel, except as otherwise specified in this specification, shall consist predominantly of refined hydrocarbons derived from conventional sources including **crude oil, natural gas liquid condensates, heavy oil, shale oil, and oil sands.** So, ASTM D7566 was created to govern the properties of jet fuel produced from any other sources, i.e. alternative.

3 https://www.icao.int/environmental-protection/GFAAF/Pages/FAQs.aspx

Currently, the ability for general and business aviation to use SAJF is limited due to inadequate production, lack of infrastructure, lack of understanding and economics. Despite this, the use of SAJF by aviation worldwide is growing, with more than 100,000 flights already flown on a blend of sustainable and conventional jet fuel, and with OEMs, airlines and others undertaking numerous demonstration flights. Today, SAJF is supplied to, and routinely used at, several major global airports, including airports in Los Angeles, US; Oslo and Bergen, Norway; and Stockholm, Sweden. Its routine use is expected to expand to airports in Geneva, Switzerland, and Brisbane, Australia, in 2018[4].

Industry Commitments on Climate Change: In November 2009, the business aviation community — comprised of the General Aviation Manufacturers Association (GAMA) representing the manufacturers, and the International Business Aviation Council (IBAC) representing the operators — announced three aspirational goals to mitigate the industry's effect on climate change[5]. These goals are:

1. To achieve carbon-neutral growth by 2020;
2. To improve fuel efficiency by 2 percent per year from 2010 until 2020, and;
3. To reduce CO_2 emissions by 50 percent by 2050 relative to 2005.

Our industry also made clear that achievement of these goals would depend on improvements across four pillars:

1. Operations more efficient operations such as reducing payload, streamlined flight planning, one-engine taxiing, etc.;
2. Infrastructure modernization of air traffic control [ATC] management;
3. Technology more efficient engines and airframes and adoption of other technologies as well as the development and commercialization of alternative fuels that deliver reductions in net lifecycle greenhouse gases versus petroleum-derived jet fuel;
4. Market-based measures as a stopgap measure until the full effect of the other pillars could be implemented.

Progress on each of these pillars requires action by our industry as well as other stakeholders and by governments.

While progress has been uneven over the past eight years, the aviation industry has kept its focus on improving efficiency via the pillars.

Operations: Operators are implementing efficiency improvements in the air and on the ground, such as one-engine taxiing, increased use of electrical ground power, more direct routing and other weight reductions on flights.

Infrastructure: Although some progress has been made, the transformation of ATC from a ground-based to a satellite-based system is behind schedule. Authorities and political leaders need to make the necessary investment in this vital infrastructure. Full modernization of ATC will bring significant system-wide efficiencies and reduce greenhouse gas (GHG) emissions.

Technology (including alternative fuels): This is the "pillar" that is the subject of this publication. Manufacturers are developing and bringing to market new engines, airframes, and other components and materials that produce improvements in fuel efficiency; they are also developing avionics that allow more efficient and safe routing, bringing additional savings.

The development and commercial deployment of sustainable alternative jet fuel (SAJF) offers the biggest "bang for the buck" when it comes to reducing the net greenhouse gas (GHG) emissions from aviation operations.

Market-Based Measures: In 2016, the International Civil Aviation Organization (ICAO) reached a global agreement to reduce carbon emissions from international aviation as part of a larger program of fostering the introduction of new technologies, ATM modernization, and operational improvements. Known as the "Carbon Offsetting and Reduction Scheme for International Aviation" (CORSIA), the agreement is aimed at limiting the growth of such emissions from 2021 onward via a carbon offsetting mechanism.

Under the CORSIA scheme, certain operators will have to offset carbon emissions from their international operations above their 2020 levels (their obligation), by purchasing approved emission credits, or by purchasing alternative fuels to lower their obligation.

In practice, CORSIA will apply to only a small percentage of business aviation operators globally. The monitoring, reporting and verification (MRV) standards currently being developed by ICAO technical bodies will define how credit will be given for the purchase of SAJF by operators to meet CORSIA obligations.

Detailed information on CORSIA can be found on the ICAO website[6]. In addition, the International Business Aviation Council (IBAC) has prepared a helpful "Countdown to CORSIA" resource page on its website with information specifically tailored for the business aviation community.[7]

4 For an up-to-date set of statistics, check www.enviro.aero/SAF
5 http://tinyurl.com/GAMA-CO_2
6 https://www.icao.int/environmental-protection/Pages/market-based-measures.aspx
7 http://www.ibac.org/business-aviation-and-the-environment/corsia

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Technical background on validation of SAJF

SAJF must have the same qualities and characteristics as conventional jet fuel in order to substitute it. This is important to ensure that manufacturers do not have to redesign engines or aircraft, and that fuel suppliers and airports do not have to build new fuel delivery systems. At present, the industry is focused on producing SAJF for a drop-in replacement to conventional jet fuel. Drop-in fuels are combined with the petroleum-based fuel either as a blend or, potentially in the future, as a 100 percent replacement.

ASTM D1655
(Standard Specification for Aviation Turbine Fuel):
Defines specific types of aviation turbine fuel for civil use in the operation and certification of aircraft, and describes fuel found satisfactory by the Original Equipment Manufacturers (OEMs) and regulatory authorities for the operation of aircraft and engines. The specification can be used as a standard in describing the quality of aviation turbine fuel from the refinery to the aircraft and covers the use of purchasing agencies in formulating specifications for purchases of aviation turbine fuel under contract. The specification covers two types (or grades) of commonly used jet fuel that differ in freeze point:

- Jet A: commercial jet fuel grade commonly used in North America (-40ºC freeze point).
- Jet A-1: jet fuel grade commonly used outside of North America (-47ºC freeze point).

ASTM D7566
(Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons):
Defines aviation turbine fuel (jet fuel) produced with synthesized components derived from non-petroleum, non-shale, and non-oil sand origin. This can include jet fuel produced from coal, natural gas, landfill recovery gas, biomass (lignocellulose, sugars, fats, oils and greases), waste streams, syngas, etc.

ASTM D1655, then, allows fuel that meets the requirements of this specification to be recertified as ASTM D1655 fuel. See the end of this document for details on the ASTM international-approved pathways to SAJF production under ASTM specification.

Before being approved by the industry for addition to the D7566 specification, SAJF must undergo strict laboratory, ground, and flight tests to ensure technical and safety compliance under an internationally-recognized standard. This rigorous and comprehensive technical review is a resource-intensive process, which takes time and considerable funding. The industry developed an ASTM standard practice that defines this process: ASTM D4054[8].

The technical requirements of a sustainable alternative jet fuel (SAJF) can be summarized thus:

- A high-performance fuel that can withstand the full range of operational conditions required to maintain the certification basis of the aircraft, engine and APU.
- A fuel that can directly substitute conventional jet fuel for aviation with no requirement for different airframe, engine, or logistical infrastructure.
- A fuel that meets or exceeds current jet fuel specifications (see discussion of D1655 above).

8 The Commercial Aviation Alternative Fuels Initiative (CAAFI) has developed a guide for ASTM D4054. It can be found at: http://www.caafi.org/resources/pdf/D4054_Users_Guide_V6_2.pdf

Testing
Safety is the aviation industry's top priority. Given this and the specific requirements of any fuels used in aircraft, the process for testing potential new fuels is particularly rigorous. Through testing in laboratories, in equipment on the ground and under the extreme conditions of in-flight operations, an exhaustive process determines suitability of SAJF.

In the laboratory
Researchers develop SAJF that has similar properties to conventional jet fuel, Jet-A or Jet A-1. This is important because fuels are used for many purposes inside the aircraft and engine, including as a lubricant, cooling fluid and hydraulic fluid, as well as for combustion.[9]

On the ground
Tests look at specific fuel consumption at several power settings from ground idle to take-off speed, which is then compared to performance with conventional jet fuel. Tests are also completed on the amount of time it takes for the engine to start, how well the fuel stays ignited in the engine and how the fuel performs in acceleration and deceleration. Tests are also completed to ensure that the fuels do not have a negative impact on the materials used in building aircraft and components. Other tests are aimed at checking APU and aircraft fuel system components (including fuel control, pumping and gauging). Finally, an emissions test determines the exhaust emissions and smoke levels for the SAJF.

In the air
Once the lab and ground tests have been completed and analyzed, the OEMs determine whether additional flight testing is needed to address any unique concerns, up to and including endurance testing. Several OEMs, airlines and operators have provided aircraft for non-conventional-fuel flight trials designed to:

- Provide data to support fuel qualification and certification for use by the aviation industry;
- Demonstrate that SAJF is safe and reliable, and
- Stimulate SAJF research and development.

During the test flight, pilots perform a number of standard tests, as well as simulating exceptional circumstances, to validate that the fuel can withstand use under any operating condition.

Approval for Specification Inclusion
The approval process has three parts: the test program; the original equipment manufacturer internal review; and a determination by the specification body as to the correct specification for the fuel. The approval process takes place in the Emerging Fuels Section of ASTM's Aviation Fuels Subcommittee. This process reviews all the evaluations of the candidate fuel versus the D1655 requirements, as well as any additional special considerations imposed by the industry depending on unique attributes associated with the alternative's feedstock or conversion process. All these properties can be found in the specification, including energy density, freezing point, volatility, thermal stability, viscosity, etc.

ASTM 4054 was developed by the engine and airplane OEMs with ASTM International member support. It was developed to provide the producer of an alternative jet fuel with guidance regarding testing and property targets necessary to evaluate a candidate alternative jet fuel.[10]

Summary – Technical Background
Civil aviation authorities and aviation industry stakeholders, including OEMs and engine manufacturers, have put in place an exhaustive and thorough process to approve SAJF. These stakeholders work closely with international fuel specification bodies, such as ASTM International to develop standards and certificates. Prior to being approved, SAJF must meet certain specifications established by the ASTM community (ASTM D7566, D1655).

Once the industry approves a production methodology, and it is added as an Annex to ASTM D7566, it can be commercialized/produced by any entity. The ASTM specifications simply identify approaches the industry has deemed acceptable to offer D1655 equivalency. Once a fuel has been fully approved, it is recognized as jet fuel and can be used without any restrictions, allowing it to be adopted by other international standards[11].

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9 In general, the synthesized fuel molecules are identical to those found in petroleum based jet fuel (pure hydrocarbons comprised of paraffins, isoparaffins, cyclo-paraffins, and aromatics in the C7-C17 chain-length range). However, they may not all be present, or present in the ratios typically found in petroleum based jet; hence the aviation community may require these fuels to be blended with jet fuel, but limited to certain maximum levels.

10 The Commercial Aviation Alternative Fuel Initiative (CAAFI) has prepared an "ASTM D4054 User's Guide" which can be found at http://www.caafi.org/resources/pdf/D4054_Users_Guide_V6_2.pdf

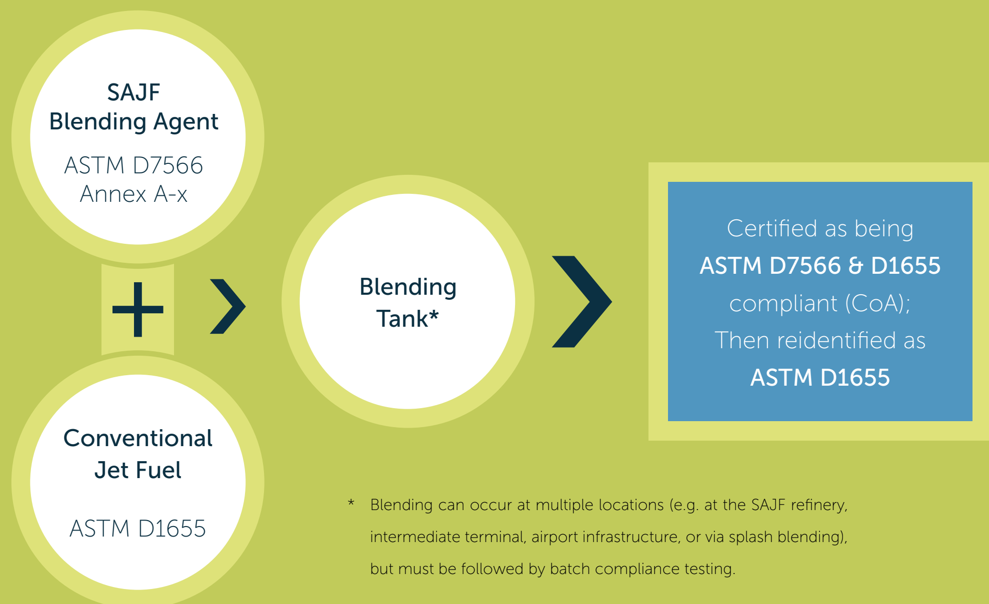
11 There are other specifications, beyond ASTM D1655, for jet fuel in various countries around the world, e.g., GOST in the former Soviet States, DEF STAN 91-91 for some British Commonwealth states, and several other country-based specs such as China (No. 3 Jet Fuel) and Brazil (QAV-1). In most cases, these specs are being updated to include new D7566 Annexes as they are added. These other standards only come into play with someone operating a non-Western certificated product whose operating manual might make a different fuel reference, or when someone attempts to purchase fuel in one of these countries where ASTM is not the standard specification.

SAJF Production Today

Any SAJF considered for use by the industry must meet all the criteria of, and be included in, ASTM D7566. These criteria apply to both the neat (i.e., un-blended) synthetic fuel component, as well as those of the blended jet fuel. That is, the alternative component must meet the requirements of the annexes therein, and it then must be blended with conventional fuel and be validated as meeting the requirements of D1655, before becoming fungible with the industry's jet fuel supply systems.

The reasons for the current blend limits are to ensure the appropriate level of safety and compatibility with the aircraft fueling systems (mainly due to maintaining a minimum level of aromatics, which are necessary for the different systems) and also to meet the density requirements of ASTM D1655. It is, however, likely that higher blend limits will be approved in the future, and that some alternative types may contain a full suite of hydrocarbon molecules that fully mimic those found in jet fuel and not require any blending.

The diagram below illustrates how conventional jet fuel is blended with SAJF and approved for technical compliance.



* Blending can occur at multiple locations (e.g. at the SAJF refinery, intermediate terminal, airport infrastructure, or via splash blending), but must be followed by batch compliance testing.

Purchasing SAJF Today

ASTM D7566 was structured to allow fuel buyers (airlines, FBOs, suppliers, operators) to use the specification as the controlling document for the physical purchase of SAJF (e.g., AltAir Fuels sells ASTM D7566 Annex A2 fuel, blended at a 30 percent level with petroleum-based, conventional jet fuel). A fuel purchaser should follow the quality control and handling procedures recommended by the SAJF supplier.

At this time, SAJF is not widely available, but this is expected to change. There are currently a limited number of airports and operators using SAJF on a routine, ongoing basis. For example, United Airlines and Gulfstream Aerospace each announced deals to purchase SAJF over three years beginning in 2016 from Alt Air's refinery in Paramount, California[12]. Business aviation manufacturers such as Bombardier, Embraer, Dassault, Gulfstream, and Textron Aviation are also working to help business jet operators increase their use of SAJF. Most of them are active as well in testing and validating the use of SAJF and have undertaken many high-profile flights using SAJF. As outlined below, the use of SAJF is steadily expanding around the globe, driven by a desire of the aviation industry to be a responsible steward of the environment to ensure the industry's continued growth.

12 See United Airlines' press release at: http://newsroom.united.com/2016-03-11-United-Airlines-Makes-History-with-Launch-of-Regularly-Scheduled-Flights-Using-Sustainable-Biofuel. The following article describes Gulfstream's initiative: http://nonstopbygulfstream.com/article/renewable-fuel-gets-green-light

Economics

The broader aviation industry has long been committed to the development of sustainable alternative jet fuel as part of its commitment to mitigate the industry's effect on climate change. The aviation industry is well positioned to be a priority user of alternative fuels within the transportation sector due to factors such as the relatively low number of operators, the prevalence of fleets (rather than individual owners of cars), high incentives (given the high proportion of airlines' fixed costs that fuel represents), a relatively small distribution network (compared to autos, for example) and an industry already committed to moving in that direction. Production of SAJF may become more economically viable and compete with fossil-based fuels as costs are lowered by improvements in production technology and through economies of scale in production, or as the price of petroleum-based jet fuel rises due to the cost of crude, cost of refining, and/or policy changes.

Since the first test flight in 2008, the technological progress has been remarkable. However, the actual uptake of alternative fuel is modest relative to total industry demand. This is in part due to these fuels still being produced in relatively small quantities. Without economies of scale, the unit cost of production remains, in general, higher than traditional fuel and this impedes its wider use. For SAJF to be scaled up to commercially viable levels, substantial capital is required to develop the refining and process capacity.

As noted earlier, there have been some forward purchase agreements from airlines and from one business aviation manufacturer. Most have been able to negotiate the fuel at only slightly higher cost than traditional jet fuel. SAJF is now routinely available and commingled with the normal fuel supply at four airports in the world: Los Angeles (LAX), Oslo and Bergen in Norway, and Stockholm, Sweden. All operators fueling aircraft at these airports are therefore already flying on Jet A or Jet A-1 blended with SAJF. There have been ad hoc bulk deliveries at many other airports, including Brisbane, Australia, Halmstad, Karlstad, and Goteborg in Sweden, and Chicago O'Hare. Geneva Cointrin and Brisbane airports plan to incorporate an SAJF blend into their normal fuel supply in 2018.

As this trend continues, new and existing producers will be able to attract more investment, while many of the largest energy companies are participating in some fashion (e.g., through joint ventures or other agreements), both efforts resulting in potential growth of the alternative fuel industry. A key factor for enabling producers to attract investment is obtaining offtake agreements. Business aviation can potentially participate in facilitating offtake via fuel suppliers, FBOs or directly.

Why Should You Use SAJF?

What is in it for your company's bottom line? There are several concrete benefits flowing from the use of SAJF. First, given the higher energy mass density (of the currently approved paraffinic types of alternatives), and depending on several factors, SAJF can be slightly more efficient than conventional Jet A for a given mission. In addition, for some of the largest business aviation operators, the implementation of CORSIA for international operations globally beginning in 2020 will provide those covered operators economic incentives to meet their obligations by increasing their use of SAJF. Also, many local, state, regional and national authorities already do, or plan to, provide fiscal and other incentives to those who produce alternative fuels, including SAJF.

And last, but not least, the use of SAJF may contribute to the achievement of your own or your company's corporate social responsibility policy objectives.

In the end, the business aviation industry must demonstrate that it remains a responsible steward of the environment if it is to preserve its ability to grow and fend off onerous regulatory and/or legislative measures that might constrain such growth.

Frequently Asked Questions - Operators and Owners

REGULATORY

Do I need special approval for my aircraft to fly with SAJF?
No, if it is produced to the requirements of ASTM D7566 and re-identified as ASTM D1655 fuel. FAA Special Airworthiness Information Bulletin (SAIB) NE-11-56R2[13] summarizes:

> *"...jet fuel made from the following synthetic blending components that meet the requirements of ASTM International Standard D7566 are acceptable for use on aircraft and engines certificated for operation with D1655 Jet A or Jet A-1 fuel if they are re-identified as D1655 fuel:*
>
> - *Fischer-Tropsch synthesized isoparaffinic kerosene (FT-SPK),*
> - *Hydroprocessed fatty acid esters and fatty acids (HEFA),*
> - *Synthesized isoparaffins (SIP),*
> - *Fischer-Tropsch synthesized kerosene with aromatics (FT-SKA), and*
> - *Alcohol-to-jet (ATJ).*

When D7566 jet fuels are re-identified as D1655 fuel, they meet all the specification requirements of D1655 fuel and, therefore, meet the approved operating limitations for aircraft and engines certificated to operate with D1655 fuel, unless otherwise prohibited by the engine or aircraft type certificate (TC) holder."

The same bulletin states the following in its recommendations:

1. *"These fuels are acceptable for use on those aircraft and engines that are approved to operate with Jet A or Jet A-1 fuels that meet the D1655 standard.*
2. *Aircraft Flight Manuals, Pilot Operating Instructions, or TCDs that specify ASTM D1655 Jet A or Jet A-1 fuel as an operating limitation do not require revision to use these fuels.*
3. *Current aircraft placards that specify Jet A or Jet A-1 fuels do not require revision and are acceptable for use with these fuels.*
4. *Operating, maintenance, or other service documents for aircraft and engines that are approved to operate with ASTM D1655 Jet A or Jet A-1 fuel do not require revision and are acceptable for use when operating with these fuels.*
5. *There are no additional or revised maintenance actions, inspections, or service requirements necessary when operating with these fuels."*[14]

How do I get my aircraft approved to fly with SAJF?
No additional approval is necessary since SAJF is ASTM D1655 compliant. It is already approved.

Do I need to register my aircraft any differently if I use SAJF?
No.

Is SAJF approved by the FAA and other CAAs?
These fuels are acceptable for use on those aircraft and engines that are approved to operate with Jet A or Jet A-1 fuels that meet the D1655 standard.[15] Refer to the above-referenced document SAIB NE-11-56R2[16]. The same is true for the European Aviation Safety Agency (EASA) as per CM-PIFS-009[17]. Transport Canada has not released any formal guidance documentation. However, if the SAJF enters the fuel distribution system as D1655, no formal guidance is required for operations already meeting their regulatory compliance (engine or aircraft manuals, or operating certificates) via the use of D1655 fuel.

TECHNICAL OPERATIONS

Does the use of SAJF have an impact on APU and main power plant performance, other components including fuel tanks and fuel systems, airframe, maintenance procedures/requirements, and/or product warranties?
Selected aircraft OEMs, engine and APU manufacturers, as well as manufacturers of other components, participated in the testing process and that testing found that SAJF is compatible for use in their products with no modifications required, and with no need for recertification or additional validation.

FLIGHT OPERATIONS

Will my aircraft perform the same under all conditions (for example, extreme hot and cold temperatures)?
SAJF blended fuel is fully approved to meet the specifications of petroleum-based fuels. This means that it performs just like conventional fuel as it meets the specifications contained in ASTM D1655.

13 http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/(LookupSAIBs)/NE-11-56R2?OpenDocument
14 http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/(LookupSAIBs)/NE-11 56R2?OpenDocumen
15 http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/(LookupSAIBs)/NE-11-56R2?OpenDocument
16 http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/(LookupSAIBs)/NE-11-56R2?OpenDocument
17 https://www.easa.europa.eu/system/files/dfu/certification-memoranda-import-EASA%20 Proposed%20CM-PIFS-009%20Issue%2001_Fuel%20Specification%20Changes.pdf

SAJF blending agents (i.e., synthetically produced hydrocarbons defined in ASTM D7566 prior to blending with conventional jet fuel) generally have a lower mass density than conventional fuels, but final SAJF blended fuels still fall within ASTM D1655 specification. They also have had slightly higher energy mass content. Operators should be aware of the specifics of the fuel and validate their range.

Do I have to fly differently?
No, SAJF does not affect how you fly the aircraft. Flight planning should consider the appropriate fuel density just as it does for conventional jet fuel.

Do I have to obtain a certificate of analysis?
No, an approved fuel certificate of analysis is not required. However, you may be able to obtain a certificate upon request from your fuel supplier.

Do I require a special placard for my aircraft?
No.

How does SAJF impact the defueling processes? Is there a special procedure?
As with all defueling operations, fuel removed from an aircraft containing SAJF should be either disposed of or returned to the aircraft from which it was removed. Persons defueling an aircraft should also contact their fuel supplier to ensure proper defueling procedures are followed.

FUEL CHARACTERISTICS

What is SAJF (Sustainable Alternative Jet Fuel)?
Jet A/A-1 fuel that meets requirements per ASTM D1655 (US), Def. Std. 91-91 (British) and CAN/CGSB-3-23 (Canadian) jet fuel specifications, whose origin is ASTM D7566 (Aviation Turbine Fuel Containing Synthesized Hydrocarbons) and is re-identified as D1655 Jet A or Jet A-1 fuel.

Is SAJF the same as alt fuel or biofuel or synthetic fuel?
There are various terms used to describe non-fossil-based hydrocarbon fuel. Often, the term "biofuel" is used. However, the aviation industry avoids this terminology as the term is not sufficiently broad to cover all envisioned feedstocks, nor does it specify the sustainability aspect of these fuels (which aviation highlights). Some biofuels, if produced from non-sustainable feedstocks, such as unsustainably-produced crops that foster significant land use change, can cause additional environmental damage, making them unsustainable for aviation's purposes.

How is it made?
SAJF is a blend of conventional Jet A/A-1 fuels and synthetic fuel blending agents produced via one of five ASTM- approved "pathways" (See ASTM D7566 Annexes 1-5).[18]

Can I mix SAJF coming from multiple feedstocks, conversion processes, or producers?
Yes, following its initial blending, SAJF is a "drop-in" fuel and can therefore be co-mingled with other equivalent specification fuel (e.g. ASTM D1655) without limitations in railway cars, fuel trucks, airport fuel storage facilities and aircraft fuel tanks.

FINANCIAL CONSIDERATIONS

Will flying with SAJF have an impact on my CORSIA contribution in the future?
The International Civil Aviation Organization (ICAO) is currently developing monitoring, reporting and verification (MRV) standards for compliance with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which enters into force in 2020 for operators that are not exempted. The proper crediting of carbon emissions reductions from the use of SAJF by covered operators is a key question being studied by technical experts at this time, but it is expected that ICAO will develop an appropriate mechanism to enable the use of SAJF to meet CORSIA obligations (e.g. credit or physical obligation reduction commensurate with the net life cycle analysis (LCA) CO_2 reduction of the SAJF purchase/used).

Is SAJF more expensive than traditional jet fuel?

Today, the cost of a sustainable blended fuel is typically higher than the price of petroleum-based Jet-A.

Can I get a financial compensation / tax break to fly on SAJF?

As noted above, those operators (generally only the largest) who may be subject to CORSIA will likely be able to meet their obligations partially via the purchase of SAJF.

Given that SAJF costs more and, as a small- to medium-sized business aviation operator, I may not even be subject to ICAO's CORSIA scheme; why should I bother using SAJF? What's in it for my company?

The business aviation industry committed in 2009 to improve its efficiency and do its part to mitigate the industry's effect on climate change.

There is considerable political pressure in many parts of the world to reduce emissions from aviation by restricting flying or imposing severe extraneous costs on it. Business aviation is often portrayed as an inefficient and wasteful mode of transportation used only by rich people.

18 https://www.astm.org/Standards/D7566.htm. ASTM website (document is for purchase).

Our industry has worked hard, with some success, to counter these myths and to emphasize the bottom-line value of business aviation to companies and to the economy. This is not enough, however. It is important for the long-term economic survival of business aviation that our industry can demonstrate through concrete measures that we are a responsible steward of the environment.

The aviation industry is in fact in the forefront of environmental responsibility and is the only industry to have developed international environmental standards for both manufacturers and operators. The industry's proactive stance has helped stave off significantly more restrictive environmental standards and regulations globally; our industry has been instrumental in designing environmentally-meaningful standards, as well as supporting national and regional regulations that also allow the industry to grow in a sustainable manner.

The commercial aviation sector is aggressively promoting its increased use of alternative fuels and other green measures in recognition of the importance of ensuring that the industry can continue to grow in a sustainable manner. It is vital that business aviation be similarly recognized for its commitment to sound environmental policies and sustainable growth. In addition, business aviation and commercial aviation share the goal of continued economic growth in a sustainable manner.

What sort of actual emissions reductions can I expect to achieve by using SAJF?

The use of SAJF results in a reduction in carbon-dioxide (CO_2) emissions across its life cycle. That is, even when considering the emissions produced in growing, transporting, harvesting, processing, and refining a particular feedstock, SAJF has been shown to provide significant reductions in overall CO_2 lifecycle emissions compared to fossil fuels.

An illustrative example: a large-cabin modern business jet on a 1,000 nautical mile mission might burn enough fuel to produce approximately 22,787 lbs. of CO_2. If such a flight were to use SAJF (HEFA-SPK pathway) produced by the Alt Air refinery in California at a blend of 30% SAJF to 70% conventional Jet-A fuel, the same mission would result in a net reduction of CO_2 emissions of approximately 4,100 lbs. (18 percent) on a lifecycle basis.

Fixed Base Operators (FBOs)

If an FBO is interested in purchasing and selling SAJF, what should it do?

It is important for an FBO desiring to sell SAJF to:

- become well acquainted in advance with the relevant ASTM D7566 standard, to ensure that only qualified fuels are involved in any supply transactions.
- understand how, if at all, the FBO could participate in the acquisition and handling of fuel to facilitate the introduction of SAJF (e.g., enabling blending of fuels on airport; taking SAJF from multiple producers).

How does an FBO receive SAJF?

The fuel supplier will arrange transportation of SAJF to the FBO. Normal fuel acceptance procedures should be used.

How does an FBO store SAJF?

The FBO should contact its fuel supplier to determine how to best store and deliver SAJF. A key factor to consider is whether the SAJF is purchased for a single client (who may desire sequestration of the fuel for fueling their specific aircraft) or for general use.

Are there special quality control procedures required for storage and delivery of SAJF?

FBOs should follow the quality control procedures recommended by their fuel supplier for the SAJF, which should tend to be identical to those used for any jet fuel.

Is special training required for FBO employees to handle SAJF?

All FBOs should provide comprehensive training in the handling of aviation fuels. FBOs should coordinate with their fuel supplier to identify any unique training requirements based upon their specific operating conditions.

Is there an industry standard for defueling an aircraft using SAJF?

As with all defueling operations, fuel removed from an aircraft containing SAJF should be either disposed of or returned to the aircraft from which it was removed. The FBO should also contact its fuel supplier to ensure proper defueling procedures are followed.

How should an FBO handle client concerns regarding compatibility of SAJF with aircraft components?

Aircraft OEMs, engine and APU manufacturers, as well as manufacturers of other components, participated in the testing process and that testing found that SAJF is compatible for use in their products with no modifications required, and with no need for recertification or additional validation.

If clients still have concerns, the FBO should direct clients to contact their OEM regarding any compatibility issues.

Additional Technical Information

Industry approved methods for SAJF production are found in the annexes of ASTM International specification D-7566, as follows:

- Annex A1: The Fischer Tropsch (FT) Synthetic Paraffinic Kerosene **(FT-SPK)** process that converts coal, natural gas or biomass into liquid hydrocarbons through an initial gasification step, followed by the Fischer-Tropsch synthesis; Blending limit: up to 50%;
- Annex A2: The Hydro-processed Esters and Fatty Acids **(HEFA-SPK)** process, which converts vegetable oils and animal fats into hydrocarbons by deoxygenation and hydro-processing; Blending limit: up to 50%;
- Annex A3: Synthetic Iso-paraffin from Hydro-processed Fermented Sugar **(HFS-SIP)**, (formerly referred to as Direct-sugar-to-Hydrocarbon (DSHC), converts sugars to pure paraffin molecules using an advanced fermentation process; Blending limit: up to 10%;
- Annex A4: Fischer Tropsch (FT) Synthetic Kerosene with Aromatics **(FT-SKA)**, adds some alkylated benzenes (e.g., from the processing of coal tar) to SPK obtained from FT coal-to-liquid; Blending limit: up to 50%;
- Annex A5: The Alcohol to Jet SPK **(ATJ-SPK)** pathway starts from an alcohol to produce an SPK (through dehydration of the alcohol to an olefinic gas, followed by oligomerization to obtain liquid olefins of a longer chain length, hydrogenation and fractionation). This annex is intended to eventually cover any C2-C5 alcohol feedstock; at present it only covers the use of iso-butanol and ethanol. Blending limit: up to 50%.

For additional information you may contact the sponsoring organizations below:

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Additional organizations and relevant resources:

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