AVIATION'S CARBON FOOTPRINT REDUCTION THROUGH SUSTAINABLE ALTERNATIVE FUELS

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Progress To-Date

The progress achieved over the last years in the development and deployment of sustainable alternative fuels for aviation (SAF) has been impressive. Before the first biofuel test flights in 2008, few experts would have believed that regular flights on biofuels would become a reality, and that within just eight years, we would see the first continuous SAF supply for airlines and airports.

The impressive achievements in SAF technology and supply development have clearly been motivated by the commitment to reduce aviation's environmental impact and especially its carbon footprint. This is supported by the entire aviation industry, governments and ICAO.

Despite significant developments in aircraft technology, and operational and infrastructural fields, the fuel efficiency improvements achieved by these means will likely not be enough to keep up with air traffic volume growth which is projected to continue at 4% to 5% annually in the coming decades. Decarbonization of air transport through the use of SAF is therefore an essential part of the strategy to achieve carbon-neutral growth from the year 2020, and the long-term goal of 50% emissions reductions by 2050 compared in comparison to 2005 levels[1].

So far, there have been two important development phases[2]:

1. 2008-2011: the test flight phase, starting with the first flight powered by a SAF blend by Virgin Atlantic in 2008, followed by an intense series of other flights using a variety of fuels from different feedstocks.
2. 2011-2015: a phase of over 2000 commercial flights powered by SAF blends, operated by 23 airlines across the globe; these started immediately after the certification of HEFA fuels for commercial flights in July 2011.

All these test and demonstration flights were carried out by individual aircraft operating on a few city-pair routes, with segregated and closely monitored fuel supply. However, by early 2016, we had reached the moment of transition - from test and demonstration flights to commercial deployment - with two major milestones recently achieved:

- On 22 January 2016, Oslo Airport started regular supply of a SAF blend through its existing common fuel distribution system. This is the first time an airport has made SAF available to all refueling aircraft, relying on existing infrastructure[3].
- On 11 March 2016, the SAF producer AltAir started regular SAF supply for United Airlines flights out of Los Angeles International Airport. These companies entered into an initial three (3) year offtake agreement at a volume of 15 million gallons (roughly 15,000 tonnes per year). This was the first in a series of– SAF supplier long-term offtake agreements with a number of airlines that was concluded in recent years[4].

Thus, regular SAF supply for commercial flights has become a reality. Various other airlines and airports are preparing similar supply chains for the coming years. Nevertheless, successful large-scale commercial deployment will depend strongly on favorable energy policy and legislation incentivizing production and use of SAF.

Technical Progress

Aviation is a global business and some airlines operate flights to/from more than a hundred countries. Therefore, it is essential that jet fuel offered anywhere in the world is compatible with the entire commercial fleet operating worldwide. Also, alternative jet fuels must be able to use the existing fuel distribution infrastructure, as building up a parallel infrastructure would be prohibitively costly. Consequently, only "drop-in" alternative fuels can be accepted, i.e. fuels which: can be blended with conventional jet fuel over reasonably wide percentage ranges, can use the existing fuel distribution system, and do not require adaptations of the engines or aircraft fuel system. The "drop-in" quality is likely to be essential for alternative jet fuels over the next few decades. The technical standards organization ASTM International has created standard D7566[5] for the certification of alternative jet fuels in this context. The physical and technical requirements that an alternative fuel must meet are essentially the same as for conventional jet fuel, and once a fuel is certified under D7566, it is considered as certified jet fuel (i.e. meeting the general jet fuel standard ASTM D1655), and can be used in the same way as conventional jet fuel without restrictions.

So far, three different SAF production pathways have been certified under the ASTM standard D7566, namely:

- Fuels produced by the Fischer-Tropsch process from any kind of biomass or other carbon-containing feedstock (2009).
- Fuels from vegetable oils or animal fats by the HEFA (hydrogenated esters and fatty acids) process (2011).
- Synthesized Iso-Paraffinic (SIP) fuels from sugars, also known as DSHC (direct sugar-to-hydrocarbon) (2014).

Six other processes are currently undergoing the ASTM

	Buyer/Investor	Seller	Volume	Investment
US Defense Production Act (DPA) Projects	U.S. DEPARTMENT OF ENERGY; USDA; DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA	Fulcrum BIOENERGY	10 MG/Yr	$70M
		EMERALD BIOFUELS	82 MG/Yr	$70M
		RED ROCK	12 MG/Yr	$70M
Supply Chain Investments	CATHAY PACIFIC	Fulcrum BIOENERGY	~35 MG/Yr	Undisclosed
	UNITED	Fulcrum BIOENERGY	~90 MG/Yr	$30M
Offtake Agreements	UNITED	AltAir Fuels	~5 MG/Yr	N/A
	Southwest	RED ROCK	3 MG/Yr	N/A
	FedEx	RED ROCK	3 MG/Yr	N/A

Figure 1. Long-term SAF offtake agreements[13].

certification process[6] and twelve more are in the preparation for ASTM certification. A very promising option among these is renewable (or "green") diesel[7], a drop-in replacement for fossil diesel, made from vegetable oils and animal fats using a similar process as for HEFA jet fuel. As this consists of a slightly different mix of hydrocarbons than jet fuel, certification would be limited to relatively low blends (probably around 10% to 15%). It has the advantage of being a product that is already available in large quantities for the automotive market, which would allow for a significant increase in the amount of SAF available in the short-term.

Each of these processes uses different kinds of feedstocks and with an increasing choice of process pathways. As such, a wide variety of feedstocks from different climatic zones will be usable, including dedicated crops, as well as residues from agriculture, forestry and animal origin, and also municipal and industrial wastes. In particular, pathways using cellulosic and ligno-cellulosic material will allow the use of abundant and cheap agricultural and forestry residues, which could offer the potential to reduce production costs for SAF.

ICAO's Alternative Fuel Task Force conducted a study, led by MIT and IATA, to estimate the potential production of SAF in the short-term (to 2020) and the long-term (to 2050). It found that up to 6.5 Mt/year of alternative jet fuel (2%-3% of global jet fuel demand) could be made available by the year 2020, assuming that renewable diesel is approved by ASTM.

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In the longer-term, the methodology involved a three-stage iteration, by assessing:

1. The constrained primary bioenergy potential;
2. How much of that bioenergy could be feasibly and economically achieved;
3. What would the ultimate jet fuel achievement be under a range of assumptions such as energy demand, finished product economics, and societal choices?

The analysis delivered a wide range of results with some scenarios showing almost no CO_2 reduction from alternative fuels, while other more favorable scenarios demonstrated that over 100% of expected 2050 international aviation jet fuel demand could be satisfied by alternative jet fuel. The clear message from this work is that, while technological feedstock yield improvements, economics and societal choice will be important, and effective and enabling policy will play a pivotal role in the ultimate outcome.

National and International Projects and Initiatives

Numerous stakeholders have to work together for the realization of SAF deployment. In addition to airlines and SAF producers and suppliers, there are numerous other players including: producers of agricultural and forestry feedstock, airports, research institutions, as well as various governmental agencies, such as aviation authorities, agencies, and ministries for transport, energy, environment and agriculture. Partnerships and joint initiatives for SAF development and deployment have been created in many countries around the globe, ranging from simple bilateral project partnerships to large multi-stakeholder associations bringing together all required expertise in a country or region and set up for long-term cooperation. A comprehensive list of these initiatives can be found in ICAO's GFAAF database[8].

As already mentioned, bilateral partnerships between airlines and SAF suppliers comprising long-term offtake agreements are powerful instruments to establish certainty of demand and to increase confidence in the stability of the alternative fuel market for aviation. **Figure 1** shows the bilateral agreements publicly announced as of early March 2016. Following the supply agreement between AltAir and United Airlines, several other partnerships are expected to start operations in the next few years. The largest of these is expected to reach 90 million gallons (270,000 tonnes) per year over 10 years.

Broader partnerships are needed that ensure SAF supply to entire airports, or "bioports", such as Oslo airport, which has been operational since January 2016. Several bioport initiatives have been launched involving cooperation among the airport, one or several major airline operators, SAF suppliers (often a trader purchasing SAF at different sources to ensure a sufficient continuous supply), and governmental institutions. A good example of this is the Bioport Holland project in Amsterdam[9]. The Canadian GARDN initiative has started a project aimed at implementing a bioport fuel supply trial at Montréal airport[10].

Multi-stakeholder associations which gather together all relevant partners from industry and government for the development and deployment of SAF have been founded in various countries. Most of these follows the example of CAAFI (Commercial Aviation Alternative Fuels Initiative)[11] in the US, but adapted to the specific situation in each country or region. The number of such initiatives is continuously increasing, in particular in countries where aviation plays an increasingly key role and in countries with favorable conditions for biofuel feedstock production. Such countries, often located in tropical regions, are interested in creating new opportunities for the local (often rural) economy (e.g. Indonesia, Malaysia, South Africa). A selection of the most relevant initiatives is listed in **Table 1**.

The Sustainability Challenge

The main impetus for airlines to use SAF is to make aviation more sustainable. Therefore most airlines that purchase SAF set robust sustainability requirements to their suppliers. As an example, all members of the Sustainable Aviation Fuels User Group (SAFUG) have signed a pledge supporting strict sustainability criteria, consistent with internationally recognized standards, such as the RSB.

A variety of regulatory and voluntary sustainability standards for biofuels is in use today[12]. Regulatory standards, such as the EU RED and the US RFS, are the basis for public incentives and for counting specific fuels towards renewable fuel or energy targets. Many biofuel producers have their products certified under voluntary standards, which usually cover a wider range of criteria, to demonstrate compliance with a wide range of environmental, social and economic sustainability criteria (see article page 163).

International aviation is very interested in global harmonization of sustainability standards to facilitate SAF purchases in different countries and recognition under different incentive schemes. With the development of ICAO's Global Market-based Measure (GMBM), which IATA thinks should give some recognition to the emissions benefits from SAF under the GMBM, it becomes necessary to define a globally harmonized set of sustainability criteria. CAEP will work on this task in its next work cycle (2016-19) in order to have an instrument ready for application at the planned entry into force of the GMBM in 2020.

The Economic Challenge

Despite the remarkable advances in the development and deployment of SAF over the last few years, the high cost of production has so far presented a major obstacle towards large-scale commercial implementation.

Long-term offtake agreements between airlines and SAF producers, such as those shown in **Figure 1**, give producers and their investors and financiers the necessary certainty for continuous demand over a longer period, which has a positive effect on loan conditions for the construction of production plants.

Consequently lower production and sales prices can be reached, approaching competitiveness with conventional jet fuel, if economies of scale and demand certainty are combined with public incentives, such as co-funding or loan guarantees for SAF production plants and a system of tradable certificates for sustainable fuels. Although competition with current low oil prices has recently made SAF purchases more challenging, it is widely recognized that engagement in SAF is a long-term investment and should not be subject to decisions based on short-term oil price fluctuations.

Need for Policy Support

Considering the important benefit for the environment, the use of renewable transport fuels is stimulated in many countries by various policy instruments such as tax rebates and blend obligations, as well as loan guarantees and other investment aids for production plants.

However, many of these incentive schemes have been tailored for land transport modes and do not directly apply to sustainable aviation fuels. Therefore, biomass or biofuel producers might be incentivized to sell their product to the land transport modes rather than the aviation market. Regulations that create a level-playing field between both sectors are vital to ensure that aviation receives its fair share of available biomass and finished fuel.

There is also growing awareness by policy makers that, contrary to land transport, aviation has no alternative to liquid hydrocarbon fuels in the short- to mid-term, and should be considered as a preferred user of sustainable fuels.

As mentioned earlier, the potential for SAF availability until 2050 strongly depends on political and economic framework conditions. CAEP has launched a study to compare the effectiveness of different policy instruments to incentivize SAF commercialization, which is intended to support governments in a growing number of countries to optimize the consideration of aviation in their renewable energy policies.

Initiative	Country/region	Website (or if missing, relevant info)
CAAFI	US	www.caafi.org
MASBI	US Midwest	www.masbi.org
SAFN	US Northwest	http://climatesolutions.org/programs/saf/resources/safn
BioFuelNet	Canada	www.biofuelnet.ca
Plan de Vuelo	Mexico	http://bioturbosina.asa.gob.mx/es_mx/BIOturbosina/Plan_de_Vuelo
ABRABA / PBB/UBRABIO	Brazil	http://cdieselbr.com.br/, www.ubrabio.com.br
Biofuels Flightpath	EU	http://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/biofuels-aviation
aireg	Germany	www.aireg.de
NISA	Nordic	www.cphcleantech.com/nisa
Bioqueroseno	Spain	www.bioqueroseno.es
Bioport Holland	Netherlands	e.g. http://www.greenaironline.com/news.php?viewStory=1904
AISAF	Australia	aisaf.org.au
ABRETF	Indonesia	e.g. http://www.core-jetfuel.eu/Shared%20Documents/Sayuta_Senobua_Aviation_Biofuel_Program_Indonesia.pdf
INAF	Japan	e.g. http://www.greenaironline.com/news.php?viewStory=1958
SEASAFI	South East Asia	e.g. http://www.greenaironline.com/news.php?viewStory=1739
Fuel Choices Initiatives	Israel	www.fuelchoicesinitiative.com

Table 1. Selection of Multi-Stakeholder Sustainable Aviation Fuel Initiatives[14]

References:

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