Overview of Biojet Fuels in 2013*

** This paper was originally published in IATA 2013 Report on Alternative Fuels as a contribution from ICAO Secretariat.*

1 Background

In under a decade, sustainable alternative fuels have emerged as a promising solution to limit aviation's greenhouse gas (GHG) emissions. Alternative fuels are among the basket of measures considered by ICAO Member States to contribute to the achievement of the global aspirational goal of stabilizing GHG emissions from international aviation at 2020 levels. Indeed, while reducing fuel consumption through technological and operational improvements remains instrumental to limiting the impact of aviation on the environment, the anticipated gains in efficiency do not fully offset the expected increase in fuel consumption resulting from the forecasted growth of air traffic for the next 40 years. When produced from renewable sources or waste, alternative fuels have the potential to bring substantial GHG emissions reductions on a life cycle basis, and may thus close part of this gap.

Considering the potential benefits of using sustainable alternative fuels in aviation and the sustained effort required for their development, ICAO convened the Conference on Aviation and Alternative Fuels in Rio de Janeiro in November 2009 inviting States to further work together through ICAO to share their efforts and strategies to accelerate the development and deployment of alternative fuels for aviation. The use of sustainable alternative fuels was endorsed as an important means of reducing aviation emissions and ICAO was tasked with facilitating and supporting initiatives for the development and deployment of these fuels, in particular the Conference adopted the ICAO Global Framework for Aviation Alternative Fuels (GFAAF) as a means of information exchange and dissemination.

A major step for sustainable alternative fuels in aviation was the approval in 2009 of the first "drop-in" fuels, i.e. fuels that are fully compatible with existing systems and that can be used just as if they were conventional fuel with no limitations in aircraft operations. The effort to develop alternative fuels with molecules and properties similar to conventional Jet A-1 ensured compliance with the stringent aviation requirements on fuel properties. As a result, the safety of operations was preserved, and any cost impact that may have been incurred due to a change in infrastructure, was avoided.

After the first approval of Fischer-Tropsch fuel in 2009, the approval of Hydroprocessed Esters and Fatty Acids (HEFA) by ASTM in 2011 opened the door to the first commercial use of sustainable alternative fuels in aviation. The number of commercial flights using HEFA fuel multiplied and, as of June 2012, more than 18 airlines had collectively performed over 1,500 commercial flights, including regularly scheduled flights.

The increase in commercial flights using alternative fuels demonstrated the technical feasibility of these fuels in aviation, and the strong interest of airlines. However, the production of these fuels is still in its early phase with only a limited volume currently available. There are still significant challenges to overcome before these fuels can represent an appreciable share of the global jet fuel supply. This article highlights the main challenges that need to be addressed and provides an overview of the recent

developments worldwide toward commercial scale deployment.

2 The challenges

While technical feasibility has been established, the price gap with conventional jet fuel in the short term is the major hurdle to stimulate the commercial deployment of alternative fuels in aviation. Economic assessments of alternative fuels for aviation converge on an initial lack of competitiveness compared to conventional jet fuel, which is likely to continue during the initial development phase before best practices, progress in production technology and economies of scale can bring about meaningful cost reductions. Incentives, or compensation mechanisms for the environmental benefits of using these fuels, are required to bridge the price gap in order for airlines to want to buy the fuels; in most cases they are nevertheless not in place. This results in a lack of a clear market perspective, which is needed to encourage investment in an emerging sector which is still perceived as being high risk.

An additional hurdle for alternative fuels in aviation is that a level playing field does not exist with the road transportation sector. Renewable energy policies in most countries support the deployment of biofuels for road transport through mandatory production quotas and fiscal incentives. In order for fuel producers to consider the aviation market, where technical requirements for fuels are more stringent, it is important that policies also consider the use of supporting measures for sustainable alternative fuels in aviation. In defining such policies, the time frame and investments required to develop the industry need to be kept in mind. Stability and long term perspective are key requirements to improving confidence and attracting investors.

Beyond supporting measures, a key to the deployment of alternative fuels in aviation is to bring costs on par with fossil fuels. This requires improving efficiency and reducing the costs of both transformation processes and feedstock production, which will necessitate further support and investments in research and development, as well as the demonstration and scale-up of technologies.

Ensuring the sustainability of deployment is also a major concern for aviation. The potential of alternative fuels for GHG emissions reductions is a strong motivator for their introduction into commercial aviation operations. Moreover, the aviation community has demonstrated its commitment to the environmental, social and economic pillars of the sustainability of alternative fuels. A large number of aviation stakeholders are represented in organizations such as the Round-table for Sustainable Biomaterials (RSB)[1] and the Sustainable Aviation Fuel User Group (SAFUG), which aim to promote sustainable practices in agriculture and energy biomass production.

The voluntary certification of alternative fuel production chains, as already initiated by some stakeholders[2] and biofuel projects[3], is part of the solution for the development of sustainable alternative jet fuels. Yet, not all of the impact of deploying alternative fuels on a commercial scale can be measured at the individual production-chain level. Therefore, there is a need for sustainability issues to be addressed at a more global level in States' policies, including at the decision-making level, in the development and implementation of sustainable biofuel policies and strategies, and in monitoring the impacts of the developments as promoted by the Global Bioenergy Partnership (GBEP), through the definition of a set of sustainability indicators for bioenergy production. Indirect impacts of developing alternative fuels, such as on the global food market or land use change in other regions due to displacement of previously existing crops, also needs to be considered, which may require specific policy measures, as well as

[1] RSB is one of the leading voluntary standard and certification schemes for the sustainability of alternative fuels

[2] The alternative fuels supplier SkyNRG has obtained RSB certification in March 2013

[3] The European ITAKA project is seeking certification for a camelina value chain.

additional methodologies and research, as there is currently no consensus on these issues.

In the efforts to ensure sustainability, given the global nature of international aviation, the emergence of different systems and regulations may cause additional challenges. Increased harmonization and the definition of mutual recognition mechanisms would be desirable to facilitate the deployment of alternative fuels on a commercial scale.

Last, sustainability is an important aspect of the long term challenge of producing sufficient quantities of feedstock for the commercial scale deployment of alternative fuels in aviation. Research in agriculture and new feedstocks, as well as on innovative processes such as those that eventually will not use biomass, remains a major axis to pursue, together with improved assessments of biomass potential, in order to establish the roadmap toward making a significant contribution to aviation's objective to limit emissions.

3 Progress in sustainable alternative fuels for aviation

3.1 Commercial use of alternative fuels

While the recent past was marked by a series of commercial flights, the number of flights operated with alternative fuels was noticeably lower over the last year, corresponding to the fact that there is no routine production of sustainable alternative jet fuel at competitive price. To date, commercial flights have operated with especially produced batches of fuels (existing hydroprocessing plants for vegetable oils and animal fats are mostly dedicated to diesel fuel).

Nonetheless, in March 2013, KLM initiated the first series of regular intercontinental flights using a blend containing 20% of HEFA, made up of used cooking oil. In order to finance the price gap with conventional jet fuel, KLM launched the "Corporate Biofuel Program" which provides KLM's business customers with the opportunity to compensate their air travel footprint by contributing to the acquisition of sustainable fuel, instead of purchasing carbon credits to offset staff travel.

In addition, Colombia entered into the pool of countries having performed commercial flights on alternative fuels with a LAN flight from Bogota to Cali in August 2013.

Several airlines have also pursued efforts to promote and support the development and deployment of sustainable alternative jet fuels by signing supply agreements with fuel producers (e.g. United Airlines with Alt Air and Alaska Airlines with Hawai'i BioEnergy) or direct cooperation agreements either for the development of technologies (e.g. Avianca Brasil with Byogy to support the "alcohol-to-jet" approval) or for the set-up of a production chain. The ICAO GFAAF[4] identifies eighteen announcements of such agreements over the last three years, five being signed in 2013.

In the frame of its agreement with United Airlines, Alt Air is now targeting the opening of a hydroprocessing plant in 2014, with a capacity of 90 kt/y of HEFA. This will be the first hydroprocessing facility capable of routine production of both renewable jet fuel and diesel. Similarly, Amyris announced the possible delivery of its sugar based biojet fuel to GOL Airlines from 2014, following regulatory approval of the fuel.

3.2 Technology developments

While Fischer-Trospsch and HEFA fuels were the first alternative fuels approved for use in aviation, numerous additional conversion processes are under development and several are currently being considered for approval by ASTM.

This includes the so called "alcohol-to-jet" (ATJ) family of processes, which begins with ethanol or butanol in order to produce jet fuel grade

[4] Global Framework for Aviation Alternative Fuels (GFAAF): http://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx

hydrocarbons (through dehydratation, oligomerisation and hydroprocessing). This route, being pursued by a number of companies (Gevo, Swedish Biofuel, Biogy, etc.), provides access to starch and sugar feedstock for the production of jet fuel and, in a second step, to lignocellulosic feedstock through enzymatic hydrolysis into sugar. In addition, ethanol production is also possible through fermentation of industrial carbon monoxide (Lanzatech, in particular, is developing such a process).

A second fermentation route from sugar, Direct Sugar to Hydrocarbon (DSHC), currently under consideration by ASTM, directly produces hydrocarbons (farnesene molecules) that are upgraded in paraffins through hydroprocessing (Amyris/Total). A demonstration flight was performed in June 2013 for Paris Air Show by a team including Total, Airbus, Air France and Safran, using a 10% blend of such fuel with kerosene[5].

Sugar can also be transformed into hydrocarbons through a catalytic process. This process, developed in particular by Virent, is also being considered by ASTM.

As for ATJ, all of the processes for converting sugar will also allow for the production of jet fuel from lignocellulose, providing access to a wide range of feedstock. Lignocellulose can also be transformed through the pyrolysis process (e.g. Kior, UOP) which produces a bio-oil which then needs to be further upgraded into jet fuel. This process, Hydrotreated Depolymerized Cellulosic Jet (DHCJ) is an additional process being considered for approval.

While the first approved processes produced only paraffins, processes that also produce synthetic aromatics are also being considered. This will open the door to the use of neat synthetic fuels. In late 2012, the Canadian company ARA demonstrated the first use of a neat biofuel on a business jet flight (the fuel was produced through hydroprocessing of vegetable oil with a preliminary catalytic hydrothermolyse that creates cyclic molecules).

[5] A first flight was achieved in June 2012 with an Embraer 195

It should be noted that approval does not necessarily mean that a pathway is ready for production. Research and development efforts are still underway for Fischer-Tropsch fuels from biomass[6], for which there is still no operational production plant.

With a view to the contribution of new production routes to the volumes of alternative fuels available for commercial use, the time frame is generally considered to be no less than ten years for a biojet pathway to reach established commercial production from the demonstration step. The reported experience in the development of advanced biofuels, such as cellulosic ethanol, also demonstrates the difficulty involved when scaling up production, both from a technical and financial point of view. Therefore, in the near term, emerging production routes cannot be anticipated to contribute large enough volumes of alternative jet fuel production.

3.3 States' and Multi-Stakeholders' initiatives

A remarkable tendency over the past years has been the growth and expansion of stakeholders initiatives and cooperation agreements worldwide. In addition to direct agreements between airlines and fuel producers, fourteen new announcements of initiatives were identified in ICAO's GFAAF as of the end of 2012, with nine more being added as of October 2013 [7] (including States' initiatives). Stakeholders' initiatives are being undertaken in all regions for the promotion and development of sustainable alternative fuels for aviation, and notably, a Memorandum of Understanding was signed recently between Boeing and South African Airways.

The spectrum of objectives covered by these initiatives includes:

- Networking and coordination of stakeholders for promotion, information exchange and road-

[6] Today only production from coal and gas is operational

[7] Only multi-stakeholders initiatives are accounted for (including those launched by States), iindividual fuel producers' activity are not included here nor State's R&D contracts or procurement.

mapping for the development of alternative fuels;

- International cooperation, such as the agreement signed between the United States and Spain and Germany, respectively (U.S.A. signed similar agreement with Brazil and Australia in 2011);
- Assessment of regional potential and solutions for alternative jet fuel production;
- Research and development;
- Setting of production value-chains;
- Other activities, such as stakeholders' coordination for fuel purchase (e.g. agreement between DEC and A4A in the U.S.A.).

Currently, a majority of initiatives aim to coordinate stakeholders for the promotion and development of alternative fuel, and/or at assessing the feasibility and the most suitable solutions for national deployment. Twelve initiatives directly targeting the development and establishment of a production

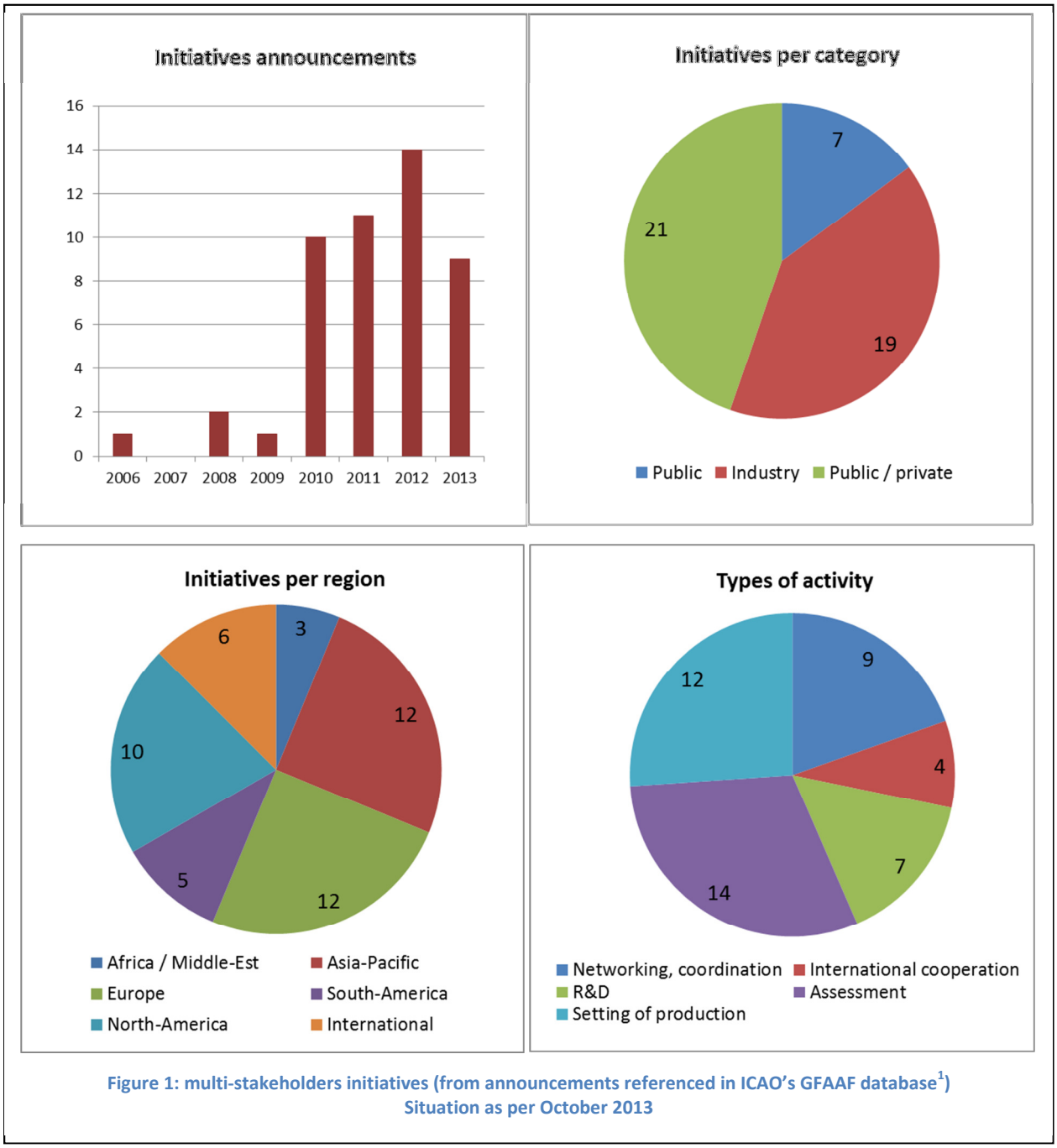

Figure 1: multi-stakeholders initiatives (from announcements referenced in ICAO's GFAAF database[1])
Situation as per October 2013

chain have nevertheless been identified.

Moreover, a significant number of initiatives from the private sector have been launched in addition to the initiatives from governments or those carried out through public-private partnerships. In particular, major aircraft manufacturers have been very active in developing regional partnerships across many regions.

Regarding States' initiatives in 2013, the Indonesian Green Aviation Initiative was notable. Indonesia is indeed the first country that has set legally binding provisions for the use of biofuels in aviation, with the target to include 2% of biofuels in aviation mix by 2016.

3.4 Outcomes of ICAO's Assembly

Since the Conference on Alternative Aviation Fuels in Rio de Janeiro in 2009, ICAO has carried out a number of initiatives to promote and support the development of sustainable alternative fuels in aviation. This includes the development of the Global Framework for Aviation Alternative Fuels (GFAAF), two dedicated workshops and the launch of the "Flightpath to a Sustainable Future" in June 2012. This symbolic initiative organized, for the first time, four connecting flights operated on biofuel blended with kerosene from Montreal to Rio for the Rio+20 summit. Also, in 2012, ICAO created the Sustainable Alternative Fuels (SUSTAF) experts group, with the mandate to issue recommendations to be presented to the 38th Assembly with a view to facilitating the emergence of alternative fuels in aviation and to supporting Member States and industry in their efforts[8].

In October 2013, the 38th Session of the ICAO Assembly reaffirmed ICAO Member States' support for the development and deployment of sustainable alternative jet fuels as part of a basket of measures to reduce aviation GHG emissions. Assembly Resolution A38-18 requests States to develop coordinated national policy actions to accelerate the appropriate development, deployment and use of sustainable alternative fuels for aviation, in accordance with their national circumstances. It also recognizes the need for the sustainable development of alternative jet fuels, according to the environmental, social and economic pillars of sustainability, and requests States to adopt measures to ensure sustainability.

4 Conclusion

The alternative jet fuels sector has proven to be quite active over the last year with more initiatives being undertaken to promote and develop these fuels, and with more countries expressing their interest. Airlines and major aircraft manufacturers have been strongly involved in these initiatives, aiming at securing the future supply of sustainable aviation fuels. Technology developments have also intensified, with an impressive number of technology companies at work and numerous processes being developed or proposed for approval.

Although routine production of bio-jet fuels is expected as of 2014, there is still a long road ahead before a significant volume of fuel could be made available for commercial aviation. This will require the expansion of supporting policies by countries to address, in particular, the price gap with conventional jet fuels while taking sustainability into account.

The reaffirmation of support from States through ICAO's Resolution on climate change and the increased number of activities and partnerships are positive signs of the willingness to foster development in this rapidly evolving sector. Cooperation among aviation stakeholders and other players from the bioenergy sector will in particular be key to addressing sustainability issues and securing access of aviation to sustainable fuels.

[8] SUSTAF's outcomes are available on the GFAAF website.