IATA 2013 Report on Alternative Fuels

Effective December 2013

8th Edition

IATA 2013 Report on Alternative Fuels

Effective December 2013

International Air Transport Association
Montreal—Geneva

8th Edition

NOTICE

DISCLAIMER. The information contained in this publication is subject to constant review in the light of changing government requirements and regulations. No subscriber or other reader should act on the basis of any such information without referring to applicable laws and regulations and/or without taking appropriate professional advice. Although every effort has been made to ensure accuracy, the International Air Transport Association shall not be held responsible for any loss or damage caused by errors, omissions, misprints or misinterpretation of the contents hereof. Furthermore, the International Air Transport Association expressly disclaims any and all liability to any person or entity, whether a purchaser of this publication or not, in respect of anything done or omitted, and the consequences of anything done or omitted, by any such person or entity in reliance on the contents of this publication.

Senior Vice President
Safety and Flight Operations
International Air Transport Association
800 Place Victoria
P.O. Box 113
Montreal, Quebec
CANADA H4Z 1M1

IATA 2013 Report on Alternative Fuels
ISBN 978-92-9252-259-9

Montreal—Geneva

Alternative Fuels Foreword 2013

Dear readers,

I am pleased to present this eighth edition of IATA's Annual Report on Alternative Fuels, describing the airline industry's perspective on the exciting field of low-carbon jet fuel. We have known for several years that sustainable biofuels could present a relatively simple solution to meeting increasing demand for air travel while simultaneously reducing our industry's carbon footprint. Indeed, many of the perceived challenges have been addressed, and the success stories continue to accumulate.

For instance, with South African Airways' recently announced biofuel initiative, there is now renewable jet fuel activity on every continent. This progress is truly amazing when you consider that it was only two years ago that the first sustainable commercial flights took place. With the number of commercial biojet flights climbing into the thousands since 2011, the question turns from whether or not biojet fuel is possible, to what can be done to further accelerate its development. The answer is multifaceted, but certainly comprises – at a minimum; reducing costs, developing supply chains, and increasing production capacity.

This edition provides further insight, contributed by some of the foremost experts in aviation biofuels, into the barriers to the deployment of biojet fuel around the world and what is being done to advance this cause. I would like to express my sincere gratitude to our friends and colleagues at the International Civil Aviation Organization, the Federal Aviation Administration, the European Commission, Massachusetts Institute of Technology, and various airlines, manufacturers, and non-governmental organizations that have provided material and without whom this report would not be possible. With the spirit of cooperation that we have witnessed in pursuing sustainable aviation solutions, I am confident our long term goals are already well within reach.

Best regards,

Günther Matschnigg
Senior Vice President, Safety and Flight Operations

Summary

The alternative jet fuels sector has remained quite active over the last year with new initiatives launched for their promotion and development and with an increasing number of countries expressing interest. Airlines and major aircraft manufacturers have been strongly involved in these initiatives, aiming at securing a future supply of sustainable aviation fuels. Technology developments are also increasing with an impressive number of technology companies at work and numerous processes being developed or proposed for approval.

Prospective alternative jet fuel producers spent 2013 generating the technical data necessary to support the ASTM International qualification process for their new fuels. Four of these producers or groups of producers have made sufficient progress in the ASTM qualification process to issue ASTM research reports for review by key aviation fuel community stakeholders. These reports contain technical data describing the fuel composition, properties, and performance in aircraft engines and test rigs. It is anticipated that the ASTM International process to review, ballot, and issue annexes for the drop-in fuel specification, D7566, will occur for one or more of these new pathways in 2014.

Different sustainability standards are in use for aviation biofuels, both regulatory and voluntary. Due to the considerable differences between these standards, there is a need for harmonization. A selection of three important standards are reviewed in this report: the Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and US Renewable Fuel Standard (RFS). The RSB has recently certified the first biojet fuel supplier (SkyNRG) and several aviation biofuel initiatives have recommended using RSB standards for their biofuel supplies. The ISCC is the most widely-used of the voluntary certification schemes that are recognized under the European Renewable Energy Directive (RED). The US Renewable Fuel Standard (RFS) provides a very effective incentive system based on tradable certificates (RINs) that are generated for each batch of biofuel.

Biojet pathways face significant cost challenges. Depending on the details of the particular pathway, the price premium of the biofuel over conventional jet fuel could be the result of high feedstock costs, high capital expenses, or some combination of the two. There are incentive structures in place in certain countries which help reduce these additional cost burdens for the fuel producer. Energy technology is expected to improve over time due to market competition, experience, and innovation, which should drive down fuel production costs, while conventional jet fuel prices are expected to increase.

Quick Facts

- Fuel specifications are defined by engine and aircraft manufacturers and approved by organizations such as the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA).
- After Fischer-Tropsch (FT) jet fuel was approved in 2009, the approval of Hydroprocessed Esters and Fatty Acids (HEFA) in 2011 catalyzed significant commercial use of biojet fuel.
- ASTM International is presently reviewing four new research reports for alternative jet fuels: (1) Alcohol to Jet Synthetic Paraffinic Kerosene, (2) Direct Sugar to Hydrocarbons, (3) FT Synthetic Paraffinic Kerosene with Aromatics, and (4) Hydroprocessed Depolymerized Cellulosic Jet.
- Commercial flights have so far typically used specially produced batches of biofuels, primarily from existing hydroprocessing plants for vegetable oils and animal fats that are mostly dedicated to diesel fuel.
- Fourteen new multi-stakeholder biojet initiatives were announced in 2012, and nine more by October 2013, bringing the total to 48.
- The average spot price of conventional jet fuel for 2013 is $0.75/L. Public data on biojet fuel prices oskudni are scarce, but early indications show a premium over biojet fuel. This difference is expected to be reduced through a variety of mechanisms including technological innovation.

Recommendations

- Governments should level the playing field by making biojet fuel incentives competitive with road biofuels. Renewable energy policies in most countries support the deployment of biofuels through mandatory production quotas and fiscal incentives. For biofuel producers to consider the aviation market there is a need for policies that also consider the use of biojet fuels with associated supporting measures. Long-term stability is a key requirement to provide confidence and attract investors.
- Increased harmonization of sustainability regulations and the definition of mutual recognition mechanisms between states would facilitate the deployment of biojet fuels at the commercial scale. Due to its global nature, international aviation is impacted by the emergence of a regional patchwork of sustainability regulations that cause additional challenges to this industry.
- A key element for achieving deployment is to bring cost down to parity with fossil fuel, which requires efficiency improvements and reduced costs of both conversion processes and feedstock production. This requires further support and investment in research and development, including demonstration and scale-up of technologies as basic elements of alternative fuels policy.

Table of Contents

Report on Alternative Fuels

1. Overview of Biojet Fuels in 2013

1.1 Chapter Summary

The alternative jet fuels sector has remained quite active over the last year with new initiatives launched for their promotion and development and with an increasing number of countries expressing interest. Airlines and major aircraft manufacturers have been strongly involved in these initiatives, aiming at securing a future supply of sustainable aviation fuels. Technology developments are also increasing with an impressive number of technology companies at work and numerous processes being developed or proposed for approval.

IATA gratefully acknowledges Jane Hupe and Philippe Novelli at ICAO for their contributions to this chapter.

1.2 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 izvodljivost 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 primetan

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.

1.3 The Challenges

While technical feasibility has been established, the price gap with conventional jet fuel in the short term is the major prepreka hurdle to stimulate the commercial razvoj 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 u rangu sa 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) 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 and biofuel projects, 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 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.

1.4 Progress in Sustainable Alternative Fuels for Aviation

1.4.1 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 značno 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 serije, količine 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[1] 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.

1.4.2 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 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[2].

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.

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

2. A first flight was achieved in June 2012 with an Embraer 195

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).

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[3], 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.

1.4.3 States' and Multi-Stakeholders' Initiatives

A remarkable tendency over the past years has been the growth and expansion of stakeholder 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[4] (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-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 the regional potential and solutions for alternative jet fuel production;
- Research and development,
- Setting of production value-chains;
- Other activities such as for example 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 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.

1.4.4 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,

3. Today only production from coal and gas is operational

4. 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.

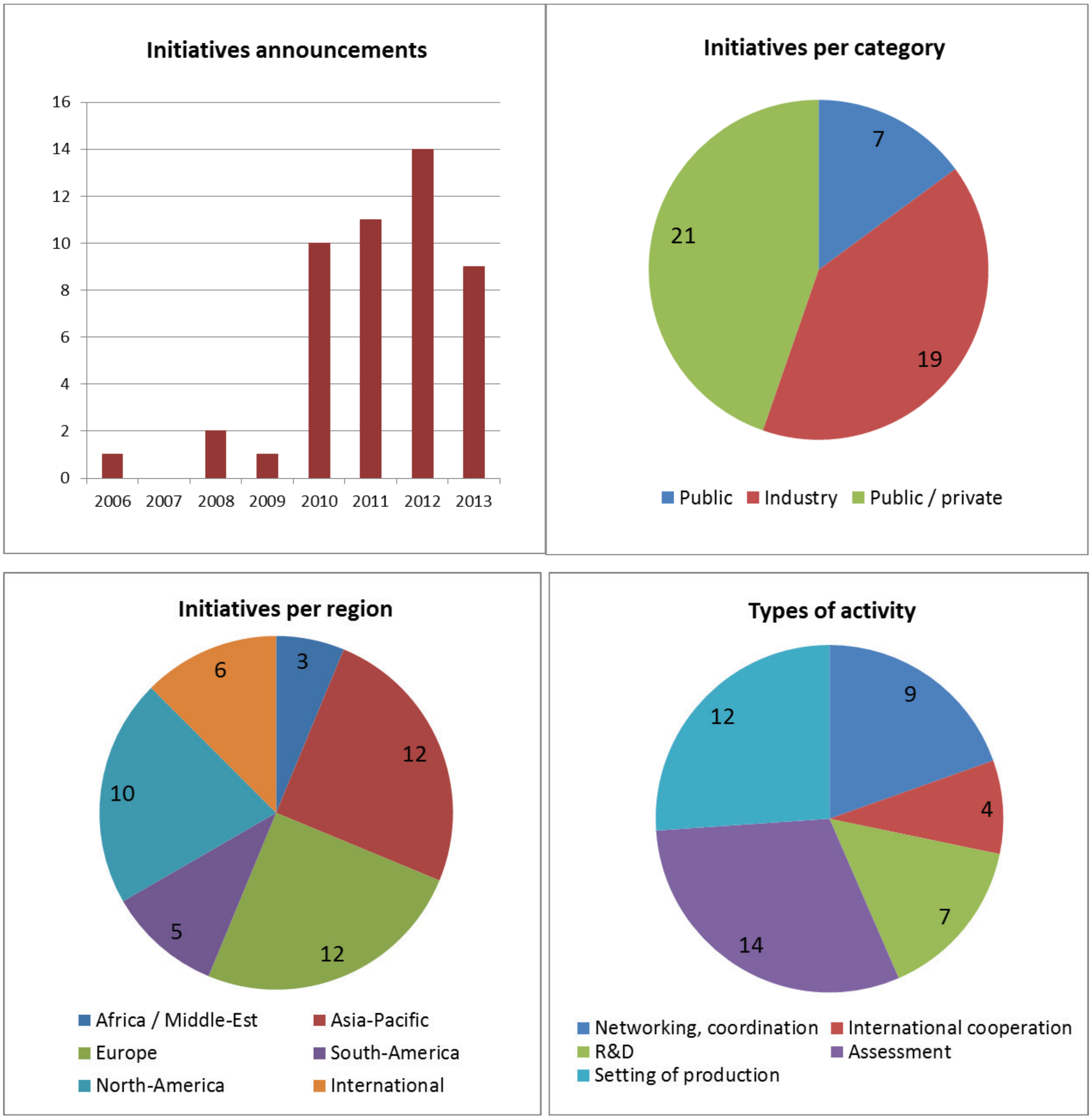


Figure 1 – multi-stakeholder initiatives (from announcements referenced in ICAO's GFAAF database[1]). Situation as of October 2013.

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[5].

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

5. SUSTAF's outcomes are available on the GFAAF website.

1

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.

1.5 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.

2. Technical Certification

2

2.1 Chapter Summary

Prospective alternative jet fuel producers spent 2013 generating the technical data necessary to support the ASTM International qualification process for their new fuels. Four of these producers, or groups of producers have made sufficient progress in the ASTM qualification process to issue ASTM research reports for review by key aviation fuel community stakeholders. These reports contain technical data describing the fuel composition, properties, and performance in aircraft engines and test rigs. It is anticipated that the ASTM International process to review, ballot, and issue annexes for the drop-in fuel specification, D7566, will occur for one or more of these new pathways in 2014.

IATA gratefully acknowledges Mark Rumizen at FAA for his contributions to this chapter.

2.2 Introduction

The design and operation of commercial aircraft is regulated by national air safety organizations or agencies, such as the Federal Aviation Administration (FAA) in the United States and the European Aviation Safety Agency (EASA) in Europe. The aviation fuel utilized by these aircraft must meet the property and performance requirements defined by the engine and aircraft manufacturers and approved by the air safety organizations.

As described in previous editions of the report, the aviation fuel community has collaborated with the FAA and EASA to develop a qualification and certification process for new, alternative drop-in jet fuels. This process utilizes the ASTM International aviation fuel subcommittee (Subcommittee J) to coordinate the evaluation of data and the establishment of specification criteria for new alternative jet fuels. Subcommittee J has issued two standards to facilitate this process; ASTM D4054 – "Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives", and ASTM D7566 – "Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons".

2.3 ASTM Approval Process for Alternative Jet Fuel

ASTM D7566 was issued in September, 2009. This specification only includes fuels that possess essentially identical compositions and performance properties to petroleum-derived Jet A/A1 fuel. These fuels are called drop-in fuels. The specification is structured with annexes that define property and compositional requirements for synthetic blending components that can be mixed with conventional, petroleum-derived jet fuel at specified volumes to result in fully-formulated drop-in fuels. It currently includes two annexes for approved drop-in fuels; Fischer Tropsch (FT) and Hydroprocess Esters and Fatty Acids (HEFA), that can blended at up to 50% volume with petroleum-derived jet fuel. D7566 includes a provision to allow fuels meeting this specification to be re-identified as conventional fuels when they enter the distribution infrastructure. ASTM International Standard D1655, 'Standard Specification for Aviation Turbine Fuels' defines the requirements for petroleum derived, conventional jet fuel. This re-identification provision allows the drop-in fuels listed in D7566 to be seamlessly integrated into the infrastructure and on to the aircraft without the need for separate tracking or regulatory approval. This is because the infrastructure is already designed to support D1655 jet fuel, and virtually all civil aircraft include "ASTM D1655 Jet A/A1 fuel" as an operating limitation and are therefore certified to operate with jet fuel meeting specification D1655. So, once a new alternative jet fuel is added as an annex to D7566, it is fit to fly on commercial airliners because it meets the existing approved aviation fuel operating limitation. Fuels that are found not to be drop-in fuels do not meet the existing approved operating limitation and must therefore undergo a separate regulatory approval process following the ASTM International qualification process (see Figure 2).

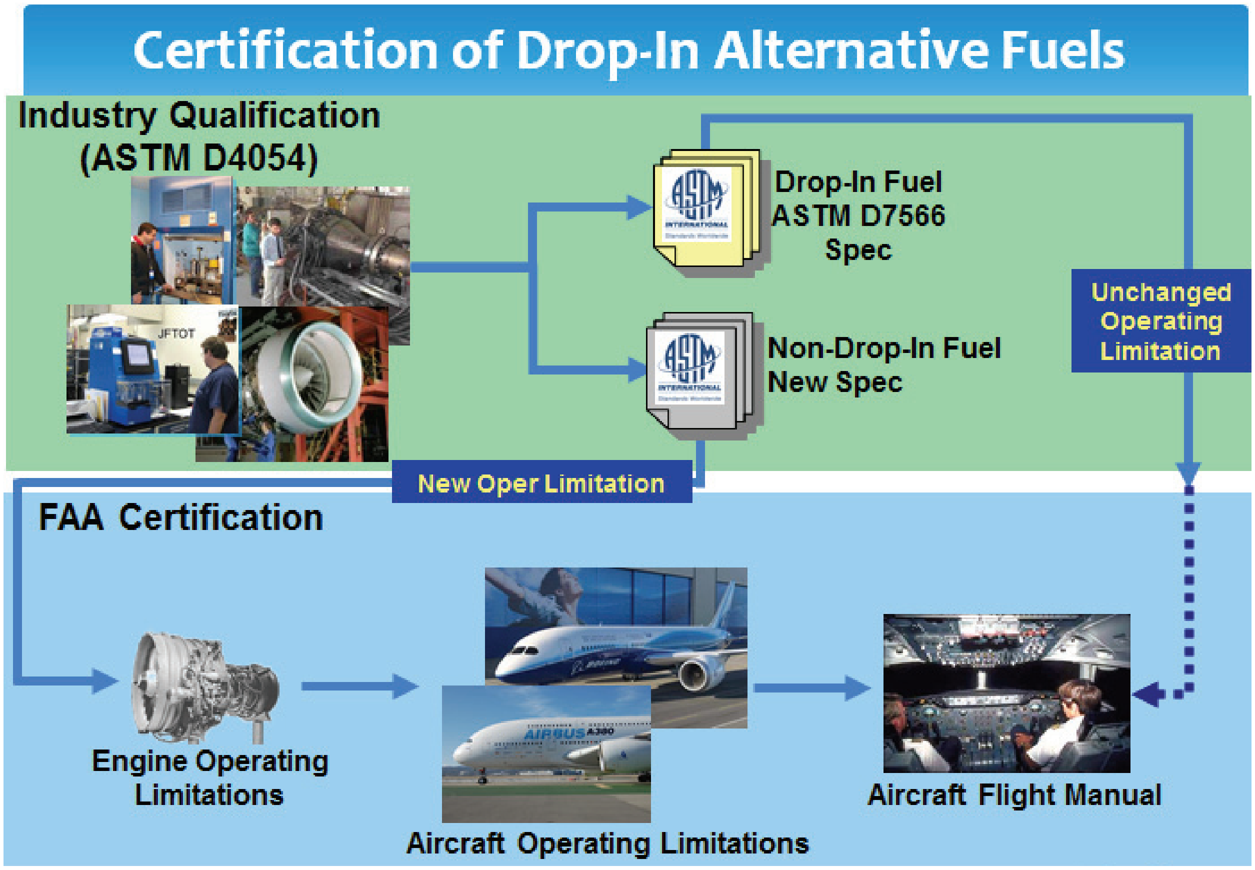


Figure 2 – Certification of Alternative Fuels

ASTM D4054 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. D4054 is an iterative process, which requires the candidate fuel developer to test samples of fuel to measure properties, composition, and performance. The testing covers basic specification properties, expanded properties called fit-for-purpose (FFP) properties, engine rig and component testing, and if necessary, full-scale engine testing (see Figure 3). This is a rigorous process that requires participation and input from many of the stakeholders at ASTM.

Typically, a producer will be seeking approval of a synthetic blending component for incorporation into D7566 as a new annex. A preliminary specification that lists the controlling properties and criteria for the neat synthetic blending component should first be established by the fuel producer prior to the initiation of the D4054 test program. The D4054 data is used to demonstrate that the proposed specification properties are sufficiently robust to ensure that all synthetic blending components meeting those properties will be fit-for-purpose for use on turbine engines and aircraft when blended with conventional jet fuel. The D4054 data must also substantiate that the proposed specification properties adequately control the blending component performance when subjected to the process variability that is expected to occur during large-scale production. The D4054 data and the proposed specification properties are then used as the basis for development of a proposed annex for incorporation into D7566 as a drop-in synthetic jet fuel. The iterative nature of this process evolves from the re-adjustment of the initial proposed specification properties that typically occurs upon review of the D4054 test results by the ASTM membership.

2

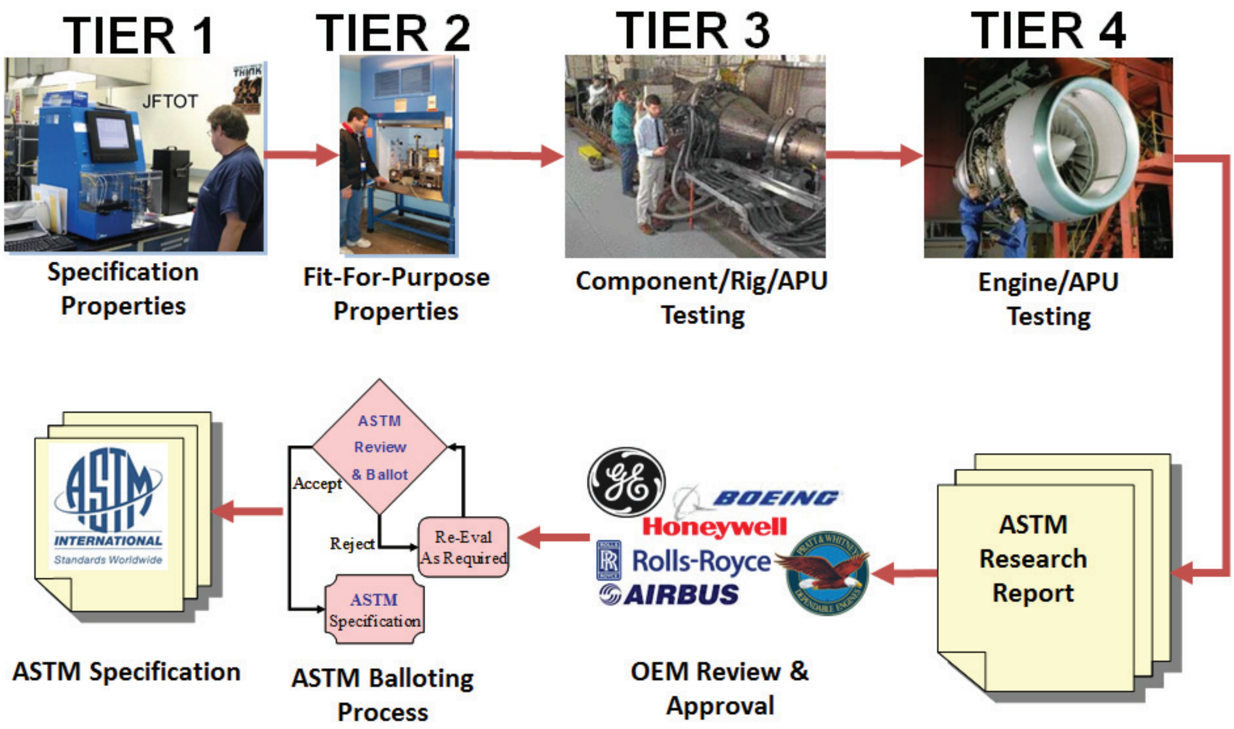


Figure 3 – ASTM D4054 Qualification Process

2.4 ASTM Research Report Overview

There are currently four draft ASTM Research Reports that are under review by key aviation fuel stakeholders in preparation for balloting to the entire ASTM membership. The ASTM task forces that submitted these reports are:

- Fischer-Tropsch Synthetic Kerosene with Aromatics (FT-SKA)
- Alcohol to Jet (ATJ)
- Hydroprocessed Depolymerized Cellulosic Jet (HDCJ)
- Direct Sugar to Hydrocarbon (DSHC)

The data contained in these reports provides the information necessary to determine if the proposed feedstock and conversion pathway produces a fuel that is fit-for-purpose (FFP) for aviation use. In essence, the fit-for-purpose of a new fuel is determined by comparison to the existing, petroleum-derived Jet A/A1 fuel. The following is a brief overview of the typical content of these research reports with examples of that content.

2.4.1 Process Description

ASTM Research Reports typically start with an overview of the pathway, or process that is used to produce the new fuel. A description of feedstock requirements, process steps, and intermediary products is provided (see Figure 4 for an example). The process description is important because it is used to establish the controlling definition of the fuel which will be specified in the D7566 specification annex.

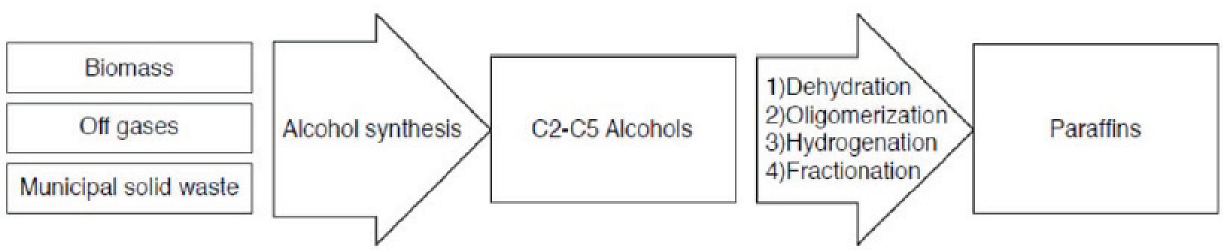


Figure 4 – ATJ-SPK Process Description (extracted from ATJ-SPK ASTM Research Report Version-October 17, 2013)

2.4.2 Tier 1 and 2 Data Section

The data analysis section of the report typically addresses the Tier 1 and 2 requirements of D4054 (see Figure 2). This section includes both tabular and graphic descriptions of fuel composition, including trace materials, of the neat, unblended synthetic fuel. This testing can be completed with relatively small volumes of test fuel ranging from 10 to 80 gallons. Sources of the fuel samples are carefully identified to facilitate presentation of data throughout this section. Figure 5 shows a chromatagram that shows the size distribution of hydrocarbon molecules that comprise the neat ATJ fuel samples. The distribution of the hydrocarbon molecules is important to ensure proper combustion in the turbine engine. This section also provides data describing the specification and FFP property test results from the laboratory tests defined in ASTM D4054. Testing results for both the unblended synthetic fuel and the blended jet fuel are provided, as applicable. Figure 6 shows the viscosity of blends of HDCJ fuel and petroleum-derived jet fuel over the operating range of aircraft engines. As can be seen in the figure by the location of the stars which represent the HDCJ samples, the HDCJ fuel is within the jet fuel experience base. This ensures that the new fuel will flow and pump properly in engines designed to operate on petroleum-derived jet fuel.

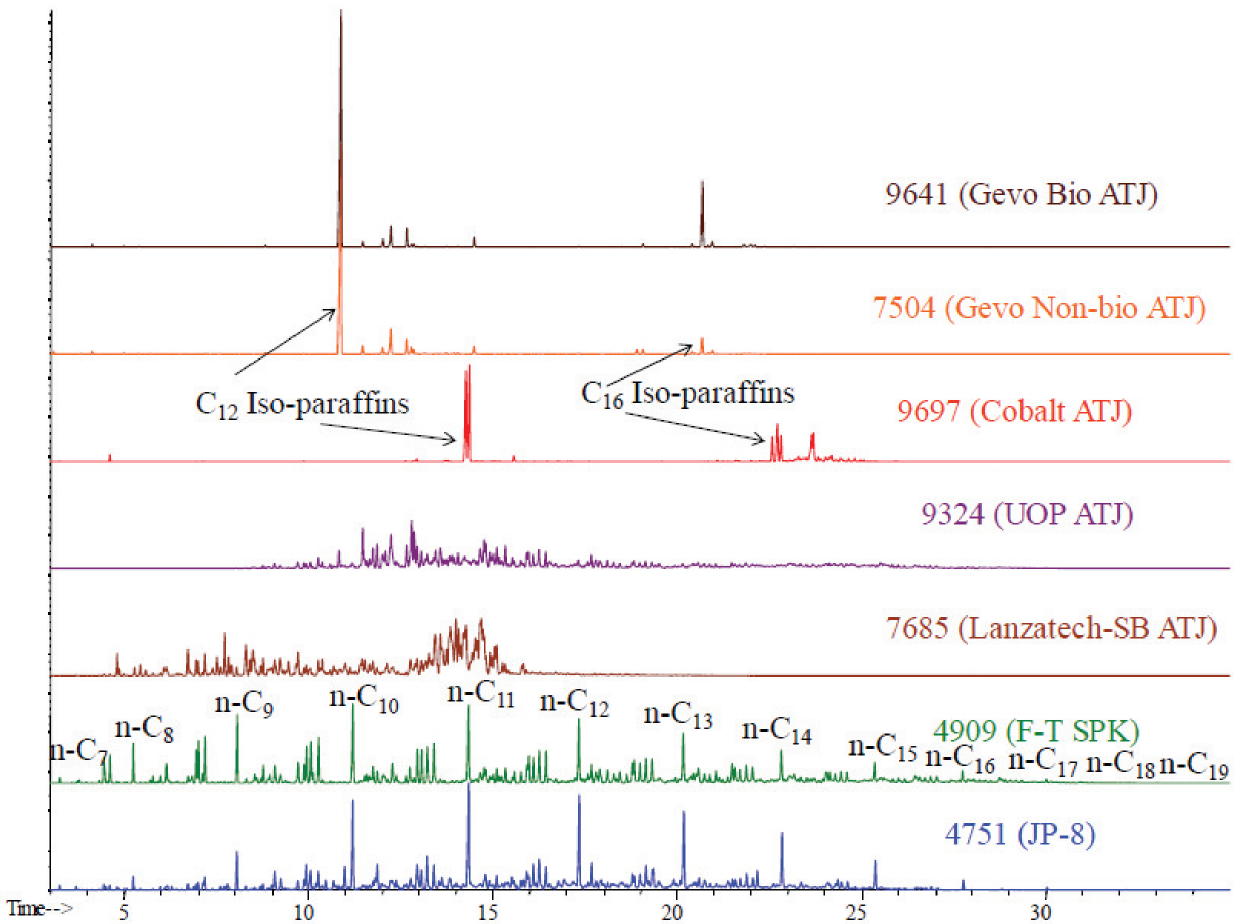


Figure 5 – Composition of Neat ATJ-SPK Samples (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

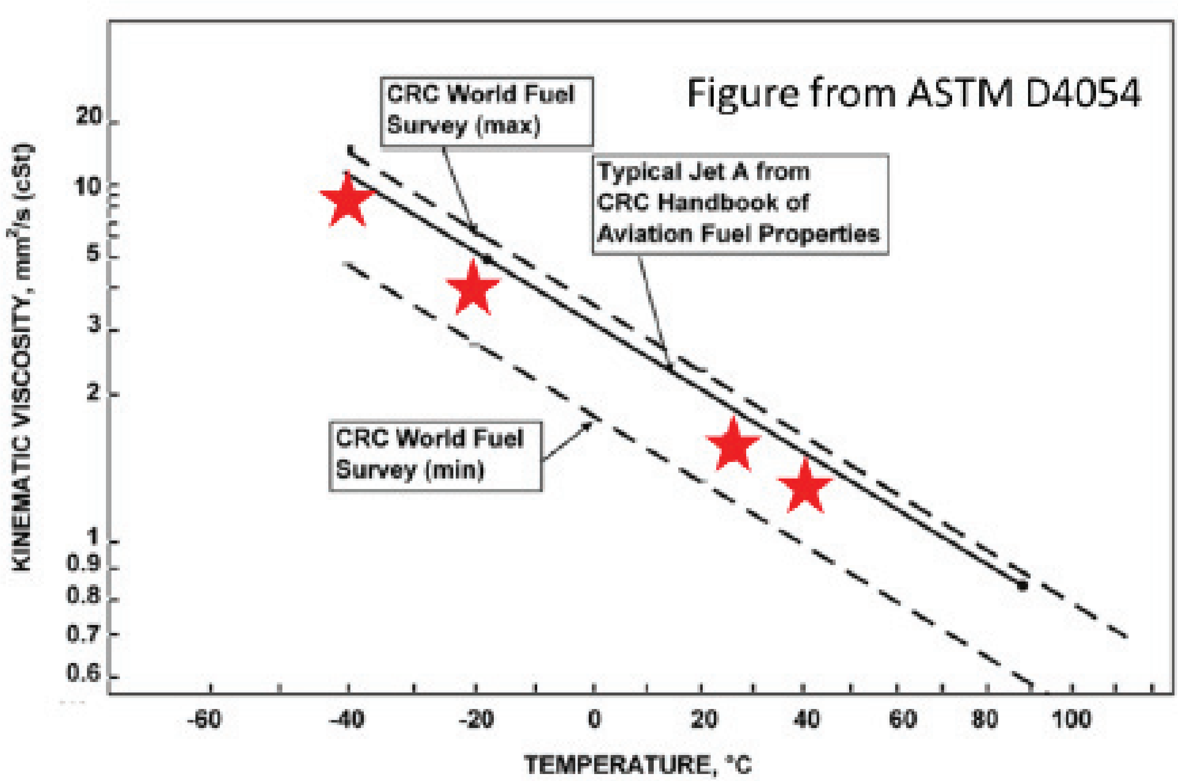


Figure 6 – Viscosity of HDCJ fuel as a function of temperature (Extracted from HDCJ ASTM Research Report Version 4, November 2012). Stars represent HDCJ samples, which fall within the acceptable range.

The Research Report also includes a section describing the compatibility of the blended fuel with both metallic and non-metallic materials that are typically in aircraft and engine fuel systems. Figure 7 shows the volume change of three different elastomeric seal materials when exposed to blends of ATJ fuel. The volume change provides an indication of the sealing ability and overall integrity of the o-ring seal.

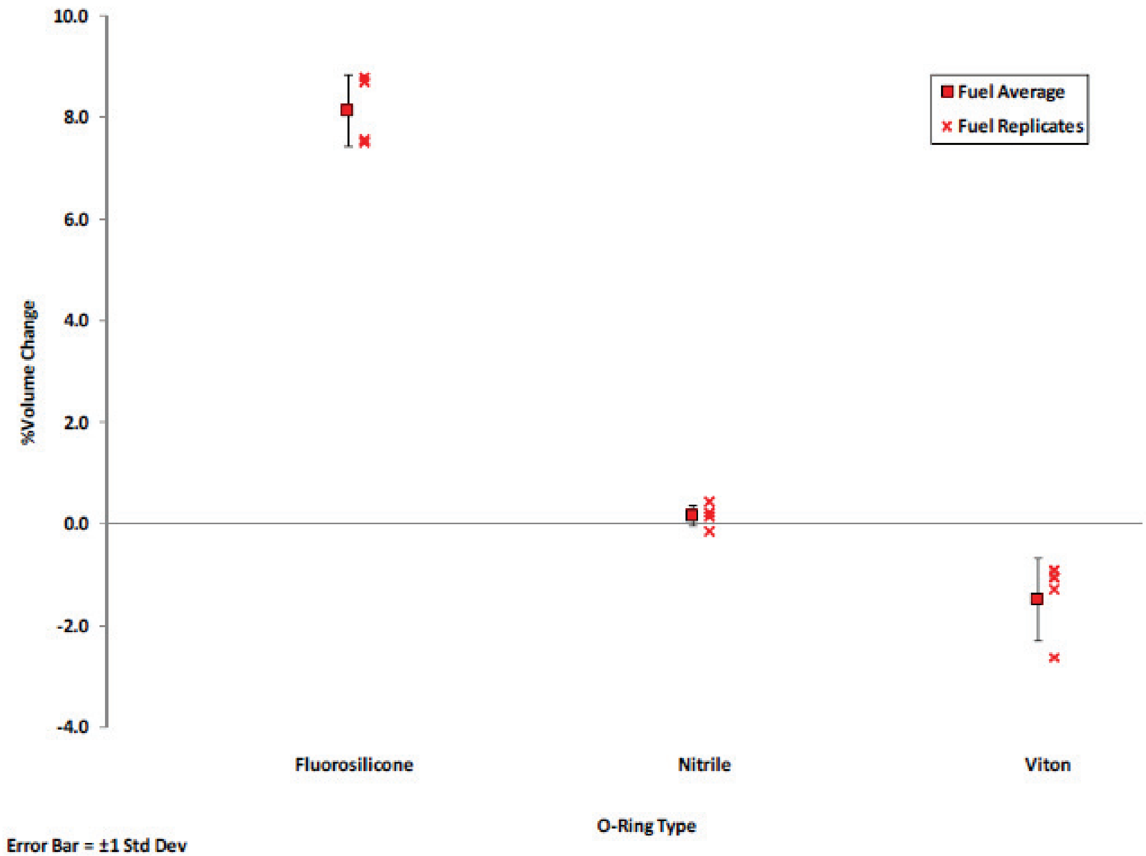


Figure 7 – Elastomeric Seal Material Compatibility of Blended ATJ Fuel (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

The FFP properties include data on many fuel performance properties, plus data on fuel handling and storage and performance in ground filtration systems. The Tier 1 and 2 data section typically concludes with an environmental and toxicology assessment which will assess the impact of the new fuel relative to petroleum-derived jet fuel.

2.4.3 Tier 3 Component/rig/ APU Testing

The fuel producers continually engage with the engine/aircraft manufacturers and other key ASTM aviation fuel subcommittee members throughout the process to solicit input on test requirements. The Tier 1 and 2 data will provide important information on the new fuel and allow the stakeholders to determine the Tier 3 test requirements. This is critical because the volume of fuel required for Tier 3 testing can vary significantly, from 250 gallons all the way up to 10,000 gallons, depending on the test requirements.

Component/rig testing typically relies on test rigs developed by engine manufacturers to evaluate fuel system or combustion system components. Figure 8 shows a fuel nozzle atomizer test rig that evaluates the fuels ability to atomize into small droplets necessary to support combustion. Figure 9 shows droplet size data that is produced by this test.

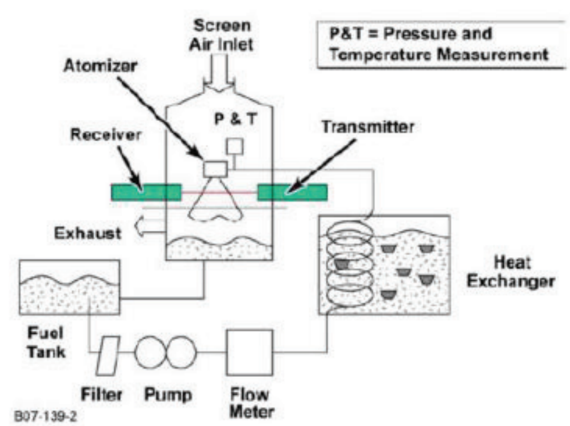


Figure 8 – Honeywell Fuel Nozzle Atomizer Test Rig (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

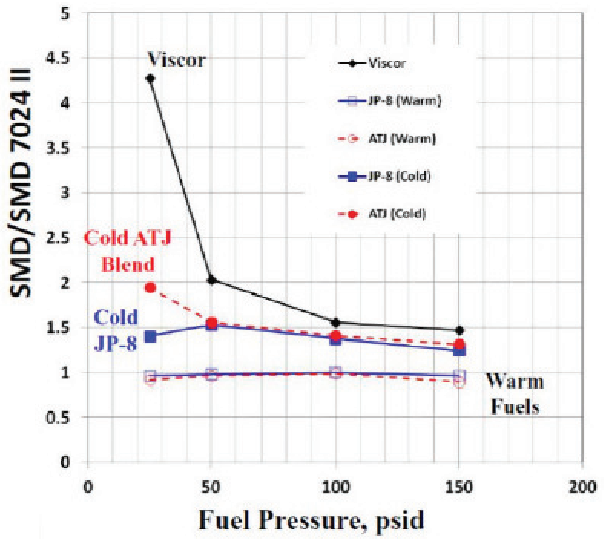


Figure 9 – Droplet Size Comparison (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

Combustor rig testing is another key test that evaluates the fuel's ability properly combust under demanding aircraft operating conditions. Figure 10 shows a combustor test rig used for this purpose. One of the most critical combustor rig tests is called the "lean blowout" test, where the fuels ability to combust at progressively lower airflows is evaluated. Figure 11 shows the results of this test.

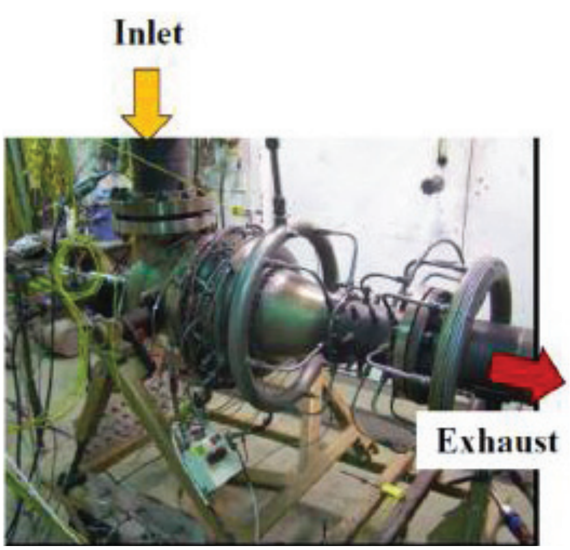


Figure 10 – Honeywell Combustor Test Rig (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

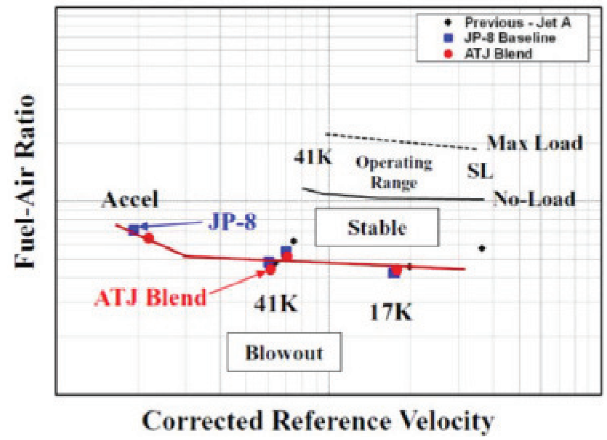


Figure 11 – Honeywell Lean Blowout Data (extracted from ATJ-SPK ASTM Research Report, Version-October 17, 2013)

2.4.4 Tier 4 Engine Testing

The initial versions of ASTM research reports frequently do not include Tier 4 engine testing. The fuel producers typically submit research reports with Tier 1, 2, and 3 data to the engine and airframe manufacturers and key stakeholders to solicit feedback regarding the need for additional testing. Depending on the Tier 4 testing requirements, between 60,000 and 225,000 gallons of test fuel could be required to support the engine testing. There are several different types of engine tests that may be included in a research report. Engine performance tests and emissions tests are relatively short duration and require the least amount of fuel. Engine endurance or durability tests are much longer duration and require the greatest fuel volumes. Figure 12 provides an overview of an engine durability test performed to evaluate HEFA fuel. The data for this test was not included in the HEFA ASTM Research Report because it was performed after approval of that fuel, but it is an example of the type of information that would be included if the durability test is required for approval.

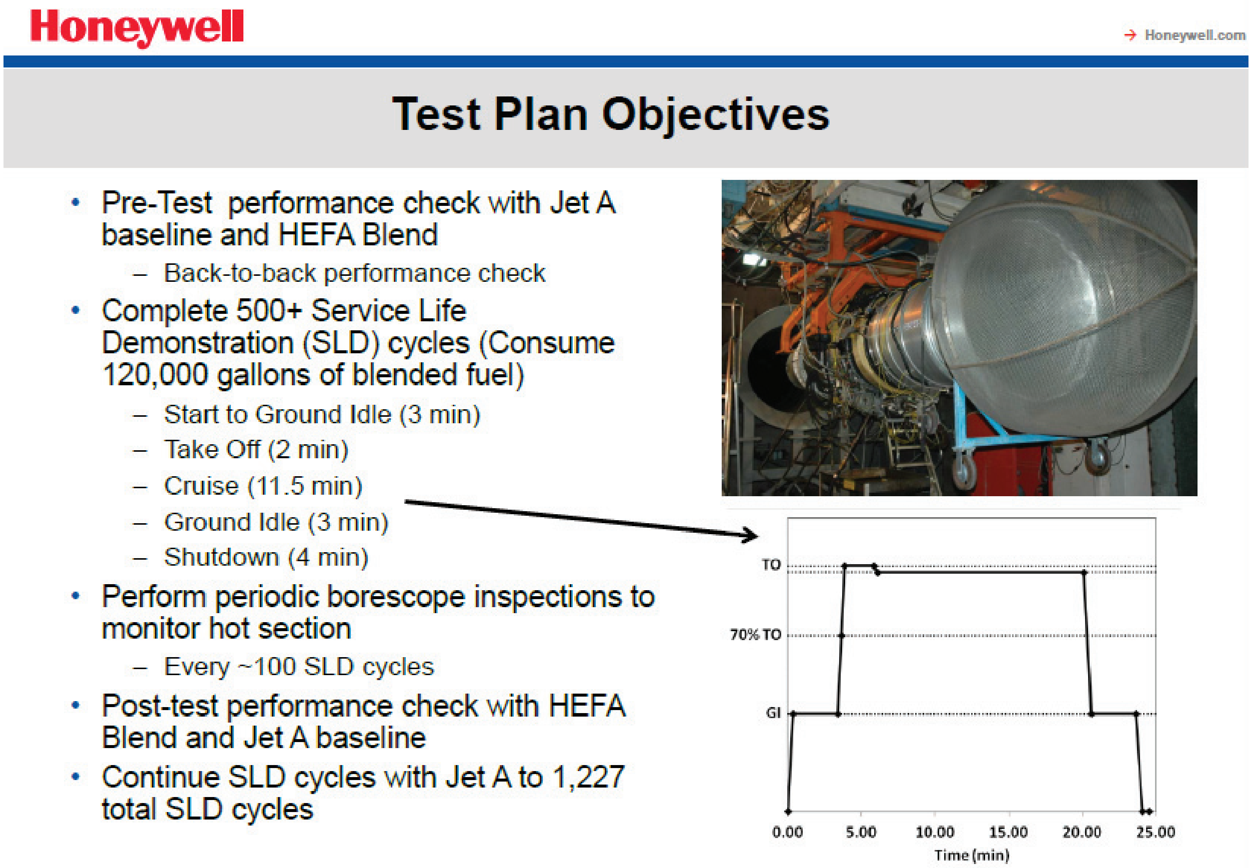


Figure 12 – Honeywell HTF7000 Engine Durability Test (extracted from 2012 CRC Aviation Fuel Meeting Presentation, “USDOT / RITA / Volpe Center Alt Fuels Propulsion Engine Durability Evaluation”, May 2, 2012)

2.5 Current Alternative Jet Fuel Certification Activity

There are currently nine active task forces in the aviation fuel subcommittee of ASTM International that are in various stages of the D4054 qualification process (see Figure 13). The following is an overview of the status of each of these task forces.

2.5.1 Approved Fuels

- FT-SPK (Fischer-Tropsch SPK[6]): The FT-SPK process converts coal, natural gas, or biomass to a synthesis gas, followed by FT processing to either long-chain paraffins or olefins. This fuel was approved as Annex A1 to ASTM D7566 in September, 2009.
- HEFA-SPK (Hydroprocessed Esters and Fatty Acids SPK): The HEFA-SPK process converts plant and animal fats and oils to hydrocarbon fuel by deoxygenation and hydroprocessing. This fuel was approved as Annex A2 to ASTM D7566 in July, 2011.

2.5.2 ASTM Task Forces With Research Reports Currently Under Review

- ATJ-SPK1 (Alcohol to Jet SPK): The ATJ-SPK process converts an alcohol feedstock to a hydrocarbon fuel. The process key steps are dehydration of the alcohol to an olefinic gas, followed by oligomerization to longer chain length liquid olefins, hydrogenation and fractionation. The research report includes a complete set of Tier 1 and Tier 2 data, along with combustor rig, fuel atomizer and engine performance test results. It is currently under preliminary review by the OEMs.
- DSHC (Direct Sugar to Hydrocarbons): The DSHC process converts sugar to a pure paraffin molecule that can be blended with jet fuel. The process utilizes an advanced fermentation process

6. SPK: Synthetic Paraffinic Kerosene

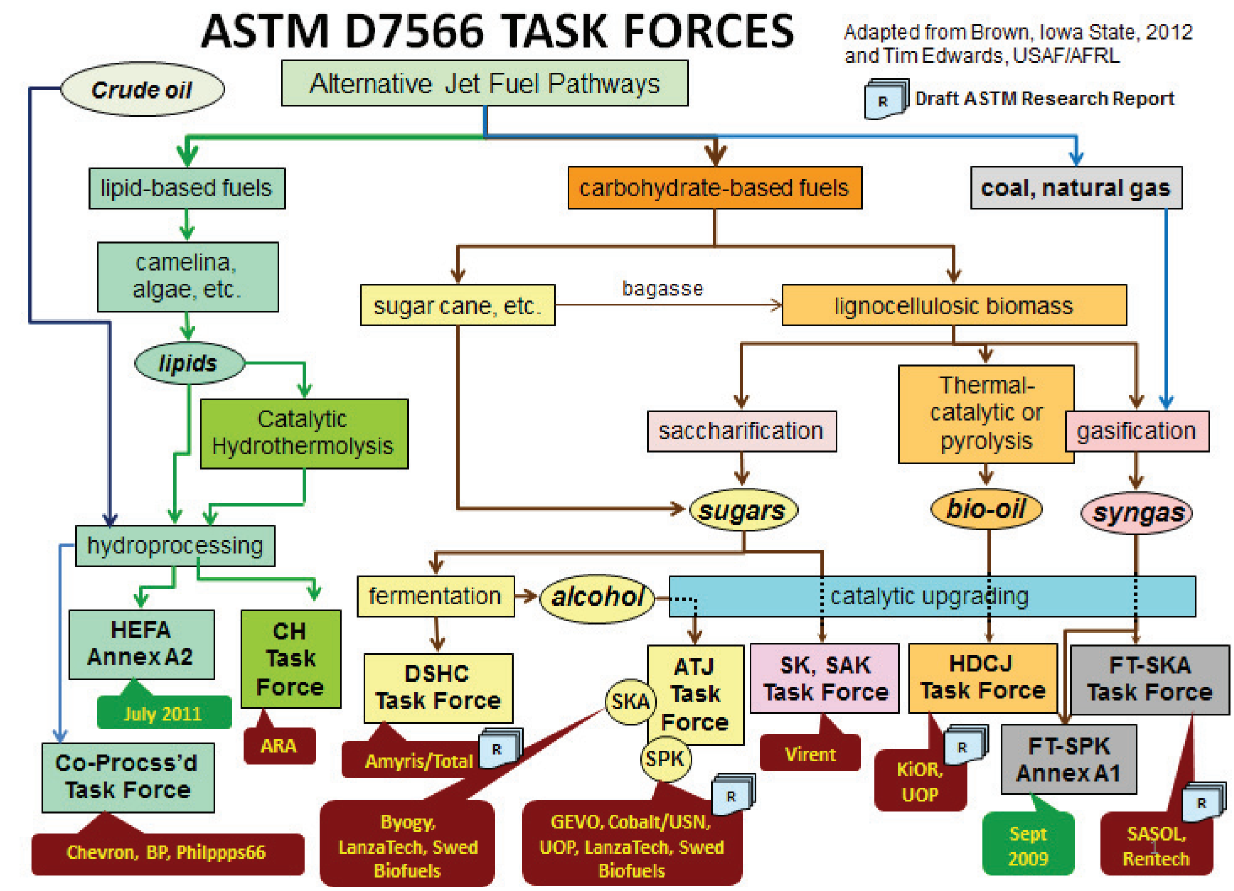


Figure 13 – ASTM Alternative Fuel Task Forces

to accomplish the conversion. The research report is currently under preliminary review by the OEMs.

- FT-SKA2 (FT Synthetic Paraffinic Kerosene with Aromatics): This is similar to the already approved FT process, but also produces synthetic aromatics along with paraffins. The research report includes Tier 1 and Tier 2 data and is currently under preliminary review by the OEMs.
- HDCJ (Hydroprocessed Depolymerized Cellulosic Jet): The HDCJ process converts lignocellulosic (woody) biomass to a hydrocarbon fuel product. This is a thermal-catalytic, or pyrolysis process that converts the biomass feedstock to a crude bio-oil. Subsequent process steps include hydroprocessing and fractionation. The research report includes a complete set of Tier 1 and Tier 2 data, along with combustor rig and engine performance test results. It is currently under preliminary review by the OEMs.

2.5.3 ASTM Task Forces Currently Compiling Test Data

- ATJ-SKA (Alcohol to Jet SKA[7]): This is a similar process to ATJ-SPK, but it produces synthetic aromatics along with paraffins.
- CH (Catalytic Hydrothermolysis): This process is similar to HEFA but utilizes water as a catalyst to convert plant and animal fats and oils to hydrocarbon fuel comprised of both paraffins and aromatics.
- SAK (Synthetic Aromatic Kerosene): This is a catalytic process that converts soluble sugars to an aromatic stream in the kerosene range.
- SK (Synthetic Kerosene): Similar to SAK, but it produces a paraffinic stream.

7. SKA: Synthetic Paraffinic Kerosene with Aromatics

2

2.5.4 New ASTM Task Forces

- Co-Processing: ASTM D7566 envisioned alternative fuels to be comprised of a petroleum-derived jet fuel blended with a separately produced and tested synthetic blending stream. This approach is reflected in the annex structure of this specification which requires testing of the synthetic blending stream to the annex criteria prior to blending with jet fuel. However, prospective fuel producers have initiated a task force to evaluate blending of the crude oil and bio-oil upstream in the production process at the hydroprocessing stage of the process. The proposed concept relies on conducting the hydroprocessing of crude petroleum with crude bio-oils in parallel to improve efficiency.

2.6 Conclusion

Prospective alternative jet fuel producers have made notable progress in 2013 towards completion of their respective ASTM qualification programs. As the aviation fuel community compiles more test data, the understanding of aviation fuel properties and composition and their effect on aircraft and engines will grow. This will lead to greater efficiencies in the alternative fuel approval process.

The aviation fuel community also eagerly anticipates the commercial deployment of these new alternative fuels, as this will also provide valuable feedback regarding the qualification process utilized to approve the fuels.

ASTM fuel specifications such as D7566 continually evolve as new experience and information is gained. The ASTM aviation fuel subcommittee looks forward to incorporating improvements in this specification as it gains more experience.

3. Sustainability

3

3.1 Chapter Summary

Different sustainability standards are in use for aviation biofuels, both regulatory and voluntary. A selection of the most relevant standards is described in more detail in this chapter. Due to the considerable differences between these standards, there is a need for harmonization.

The three standards reviewed in this chapter are the Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and US Renewable Fuel Standard (RFS). The RSB has recently certified the first biojet fuel supplier (SkyNRG) and several aviation biofuel initiatives have recommended using RSB standards for their biofuel supplies. The ISCC is the most widely-used of the voluntary certification schemes that are recognized under the European Renewable Energy Directive (RED). The US RFS provides a very effective incentive system based on tradable certificates (RINs) that are generated for each batch of biofuel.

IATA gratefully acknowledges Rolf Hogan at RSB and Andreas Feige at ISCC for their contributions to this chapter.

3.2 Introduction

Throughout the history of aviation there has been a continuous improvement of fuel efficiency, driven by the necessity to save weight and costs, and increasingly by environmental considerations. Only in the last decade have possibilities emerged to replace conventional jet fuel by more sustainable alternatives.

Following developments in land transport, biofuels became a promising choice of a sustainable alternative energy for aviation because of their reduced net carbon dioxide emissions compared to fossil fuels. For aviation there are no other sustainable alternative energies available in the near-to-mid-term, contrary to the automotive sector which already offers solutions using electric batteries and fuel cells. It is however essential that, in addition to greenhouse gas savings, other environmental, societal and economic aspects of sustainability are also respected in biofuel production and use. Influenced by the experience with poor sustainability of various first-generation biofuel feedstocks for land transport, the aviation industry has been focusing on sustainability as a main requirement from the beginning of their engagement in biofuels.

There are a variety of regulatory and voluntary sustainability standards that are applicable to aviation biofuels. The present chapter reports on the latest developments in some of them.

Biofuel sustainability regulations in force in various countries show considerable differences in scope and procedures, especially between the EU RED and the US RFS. An example of this are the methodologies used to determine lifecycle greenhouse gas emissions. For aviation as a global activity it is essential to remove obstacles stemming from such regulatory differences to enhance the uptake of biofuels by airlines.

The United Nations International Civil Aviation Organisation (ICAO) supports this need, and its Sustainable Aviation Fuels Expert Group (SUSTAF) has made respective recommendations to the 38th ICAO Assembly, held in Montréal in September / October 2013. The ICAO Resolution A38-18 on Climate Change strongly promotes the use of sustainable alternative aviation fuels and contains a number of requirements to ensure the sustainability of these fuels.

3

A landmark agreement on Climate Change was reached with the ICAO Resolution 38-18. The agreement commits ICAO to developing a global market based measure that will be an essential enabler for the industry to achieve carbon neutral growth from 2020. The agreement will set in motion the detailed design elements for the monitoring, reporting and verification of emissions and the type of scheme to be implemented. It was agreed to apply the ICAO guiding principles when designing MBMs in an effort to avoid duplication, carbon leakage and market distortions and address non-discrimination. Full resolution details can be found elsewhere[8].

3.3 Roundtable on Sustainable Biomaterials

2013 has seen steady progress on biofuel sustainability in aviation through wider commitment to the RSB standard and the first RSB-certified biojet coming online. The Natural Resource Defense Council called for stronger commitment to the RSB by the sector and Midwest Sustainable Aviation Biofuels Initiative (MASBI) recognized the standard in its findings. The RSB multi-stakeholder process has also endorsed an approach to address the indirect impacts of biofuels which will allow airlines to identify RSB certified fuels that have not displaced food production or led to the destruction of natural habitats. The months ahead look set for further progress on sustainability as the RSB-Boeing initiative to encourage certification of small farmers picks up speed.

It has been a busy year for RSB with a newly independent secretariat being established in Geneva, the expansion of scope of the standard into biomaterials and the adoption of a new name “Roundtable on Sustainable Biomaterials”. The expansion of scope allows the certification of other forms of bioenergy such as biogas as well as a range of materials produced from biomass including bio-plastics and lubricants. The new Secretariat has been busy streamlining the standard to make it more user-friendly and revising the standard in line with the expansion of scope.

Since the RSB has been extensively described in previous IATA Reports on Alternative Fuels (available on IATA’s website), the following sections describe some notable developments that have taken place over the past year.

3.3.1 First RSB-certified Biojet Fuel Now Available

In March 2013, for the first time ever, RSB-certified jet became available with the certification of SkyNRG and its supplier Dynamic Fuels. Dynamic produces drop-in fuels from animal fats, greases, and vegetable oils and SkyNRG supplies more than 15 carriers worldwide including KLM. It provided the biofuel for a series its transatlantic flights from Amsterdam to New York also inaugurated in March.

3.3.2 Biojet Fuel Feedstock Certified in Spain

Camelina Company España (CCE) a joint venture with Great Plains Oil & Exploration became RSB-certified in October. The certification covers over 150 farmers as well as several of Camelina Company’s facilities. The camelina is grown as a rotation crop in arid regions of Spain where it does not replace food crops or cause direct or indirect land use change. CCE is part of ITAKA (Initiative Towards sustAinable Kerosene for Aviation) which aims to speed up the commercialization of aviation biofuels in Europe. Other ITAKA partners include RSB members Airbus, Neste Oil and SkyNRG.

3.3.3 Sourcing Sustainable Fuels

In a purchasing deal for 57 million litres (15 million gallons) of biojet fuel signed in June, United Airlines stated their support for AltAir Fuels’ efforts to incorporate internationally recognized sustainability standards, such as the RSB. In July, Alaska Airlines and Hawaii BioEnergy announced an agreement for the carrier to purchase sustainable biofuel. The feedstock for the biofuel was announced as woody biomass-based and is consistent with RSB sustainability criteria.

8. https://www.iata.org/pressroom/pr/Documents/agm69-resolution-cng2020.pdf

3.3.4 Advocating Sustainability

The Natural Resource Defense Council (NRDC) urged the aviation industry to step up its commitment to purchasing RSB-certified fuel to ensure true sustainability in the sector. The NRDC report *Aviation Biofuel – Sustainability Survey*, published in March 2013, provides a detailed independent review of sustainability issues across the sector including potential indirect impacts associated with the supplies of biojet fuels.

3.3.5 Midwest Aviation Sustainable Biofuels Initiative

In the USA, in June 2013 the Midwest Aviation Sustainable Biofuels Initiative (MASBI) published its findings recommending the use of sustainability criteria consistent with international credible standards such as the RSB. This initiative, led by United Airlines, Boeing, the city of Chicago, Honeywell's UOP and Clean Energy Trust, echoes the findings of similar initiatives in Brazil, Mexico, Australia, New Zealand and the US Pacific Northwest.

3.3.6 Brazil Biofuels Platform

RSB Services Foundation, the organisation created and licenced to implement the RSB certification system, has joined with other stakeholders in the Brazil Biojet Platform (BBP) including GOL Airlines, Boeing, Amyris, Solazyme and others as the sustainability partner. The goal of the BBP is to bring together stakeholders for integration, optimization and development of a sustainable biojet fuel supply chain in Brazil. Stakeholders representing technology, feedstock production, airlines, and fuel producers who have joined the initiative will also serve as the private sector interface for US-Brazil Biojetfuel Bilateral Agreement.

3.3.7 Promoting Smallholder Production with Boeing's Global Corporate Citizenship Program

With the help of Boeing's Global Corporate Citizenship program the RSB has launched an initiative to promote the integration of the RSB standard into rural development. The program should lead to an increased production of sustainable biofuel while supporting the livelihoods of small farmers. RSB certification is meant to increase the access of smallholders to export markets and to promote sustainable production. The program kicked-off in Southeast Asia with the preparation of a series of case studies to identify difficulties that smallholders experience in becoming certified, and testing a new version of the RSB standard for smallholders.

A workshop in Kuala Lumpur in December 2013 will bring together development agencies and governments to look at how they can integrate RSB certification into rural development programs and improve the livelihoods of small-scale farmers. A similar initiative for Latin America will be launched in Mexico in November 2013 and continue in 2014 along with work in Africa. National development agencies in Norway and Switzerland are contributing to the smallholder initiative as well as RSB members such as the National Wildlife Federation and the Inter-America Development Bank. Boeing and RSB are seeking additional partners for this initiative.

3.3.8 Ensuring Low Indirect Impact Biofuels

In March 2013, the RSB approved an approach to recognise biofuels with low indirect impact The Assembly of Delegates, which represents the RSB's diverse membership, approved the use of the *Low Indirect Impact Biofuels (LIIB)* methodology[9] developed jointly by WWF International, Ecole Polytechnique Fédérale de Lausanne (the former institutional home of the RSB) and Ecofys. The methodology promotes practices that reduce the risk of displacement and competition with food production and biodiversity conservation. Approaches include: the use of wastes and residues, increasing yields, intercropping, and the use of abandoned lands.

Indirect impacts of biofuels (and biomaterials) have been under discussion for some time with little consensus on how to best address them. Indirect impacts include conversion of natural habitat to agriculture or increased food prices as a result of biomass being diverted for energy. While the existence of such effects is generally accepted, the scale and exact contribution of biofuels in the recent surge of food prices are heavily disputed. This is why attempts to quantify or model indirect impacts – as in the case of iLUC factors – are subject to controversy.

9. http://www.liib.org

The issue stimulated considerable discussion within the RSB membership and led to an extensive consultation process in 2012. The decision by the RSB membership will allow for operators undergoing certification to opt for a voluntary module that will verify that their fuel or biomaterial has low risk of causing indirect impact.

3.3.9 Fast-track Certification of Fuels from Forest Residues

The certification of biofuel production from forest residues will be facilitated by a simplified audit process for forest management certified by the Forest Stewardship Council (FSC). Thanks to a comparative analysis of the RSB and FSC standards, which identified gaps and areas of overlap, FSC-certified operators will be able to receive RSB certification by demonstrating compliance only with those RSB requirements which are not already covered by their FSC certification. The main gaps are greenhouse gas calculation and food security. Similar comparative studies are nearing completion for the Bonsuccro standard and the International Finance Corporation (IFC) Sustainability Framework Performance Standards.

3.4 The US Renewable Fuels Standard (RFS)

The US Environmental Protection Agency is responsible for developing and implementing regulations to ensure that transportation fuel sold in the United States contains a minimum volume of renewable fuel.

The RFS was created under the Energy Policy Act of 2005 and expanded in the Energy Independence and Security Act of 2007 (EISA). The expanded RFS (referred to as RFS2) established a mandate objective of 36 billion gallons of biofuel use by 2022. While the program is focused on ground transportation, entities producing biomass based jet fuel can qualify for financial credit under the system.

RFS2 has the following three key properties:

1. The total renewable fuel requirement is divided into four separate, but nested categories, each with its own volume requirement.
2. Biofuels qualifying under each category must achieve certain minimum thresholds of lifecycle greenhouse gas emission reductions.
3. All renewable fuel must be made from feedstock that meets an amended definition of renewable biomass, including certain land use restrictions.

RFS2 includes four biofuel categories, each with a specific volume mandate and lifecycle GHG emissions reduction threshold. To qualify under RFS2, each must reduce GHG emissions relative to its fossil equivalent according to the following schedule:

Biofuels category	Threshold reduction[10]
Conventional biofuel	20%
Advanced biofuel (cellulosic)	50%
Advanced biofuel (biomass-based diesel)	50%
Advanced biofuel (unspecified)	60%

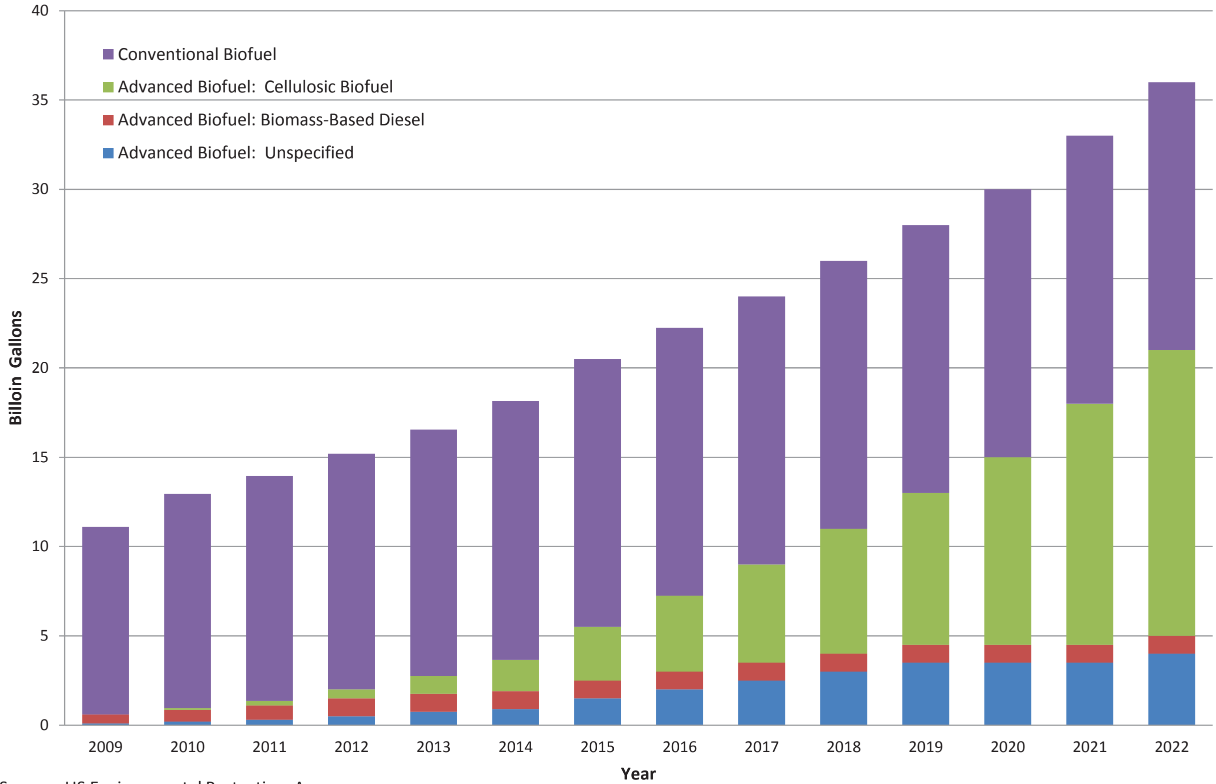
Table 1 – EISA-mandated reductions in lifecycle greenhouse gas emissions (percent reduction from 2005 baseline for gasoline or diesel fuel)

3.4.1 Renewable Identification Numbers under the RFS

Currently, only gasoline and diesel fuels are subject to quota requirements, which is a deliberate design strategy. However, renewable jet fuel can generate Renewable Identification Numbers (RINs) if there is an approved fuel pathway and all other requirements are met. A RIN is a unique 38 character number that is issued by the biofuel producer or importer at the point of biofuel production or the port of importation. It derives a value based on supply and demand fundamentals for each biofuel category, and whether the blending mandate is binding.

RINs can only be generated if it can be established that the feedstock from which the fuel was made meets EISA's definition of renewable biomass. A key financial facet of the RIN system is when a renewable fuel is blended for retail sale or at the point of embarkation for export, the RIN is separated from the fuel and may be used for compliance or trade. Given the challenges of financing large scale biojet fuel supply infrastructure, the RIN system is one tool that can potentially accelerate the development of renewable jet fuel production.

10. Source: "Regulatory Announcement EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010," EPA-420-F-10-007, Office of Transportation and Air Quality, EPA, February 3, 2010.



Source: US Environmental Protection Agency

Figure 14 – RFS2 renewable fuel volume requirements

3.4.2 Biojet Fuel Under the RFS

In March 2010 RFS2 final rule included pathways for jet fuel from several different feedstocks. These included:

- The non-cellulosic portions of separated food waste
- Cellulosic Biomass from crop residue, slash, pre-commercial thinnings and tree residue, annual covercrops, switchgrass, and miscanthus
- Cellulosic components of separated yard waste
- Cellulosic components of separated food waste
- Cellulosic components of separated MSW

Recently, in March 2013, the EPA approved several new biojetfuel pathways which include:

- Jet fuel produced from camelina oil using a hydrotreating process. This qualifies for biomass-based diesel and advanced biofuel RINs
- Clarified the definition of renewable diesel to explicitly include jet fuel.
- Jet fuel produced from soybean oil, oil from annual cover crops, algal oil, biogenic waste oils/fats/greases, and non-food grade corn oil now qualifies for biomass-based diesel and advanced biofuel RINs.

A number of additional pathways remain under consideration and are likely to evolve in the medium term. The EPA has set up a petition process for evaluation of new renewable fuel pathways. Pathways currently under review through the petition process include the following:

- Hydrotreated hetrotrophic algal oil
- Hydrotreated jatropha oil

As both the RED and RFS continue to mature and evolve, and particularly in the context of the ICAO resolution of Sept/Oct 2013, it becomes increasingly relevant to address cross recognition of sustainability standards and possible harmonization.

3.5 International Sustainability and Carbon Certification (ISCC)

International Sustainability and Carbon Certification (ISCC) is described as the world's first state-recognized certification system for sustainability and GHG savings that can be applied to all kinds of biomass, waste and residues related biofuels and biojet fuels. The ISCC certification system became operational in 2010 and has been developed with the involvement of more than 250 stakeholders from Europe, America and Southeast Asia since 2006. ISCC headquarters are located in Cologne, Germany. ISCC is employed by more than 2000 system users in 81 countries worldwide. It certifies that biomass was produced in compliance with high environmental and social standards, providing reliability and credibility for system users. ISCC was officially recognized for biofuels by the German authorities in 2010 and by the European Commission in mid-2011. In addition to the system for biofuels, ISCC PLUS was launched in 2012 and offers market participants and producers from the food, feed, chemical and pharmaceutical industry the opportunity to achieve sustainability certification for all types of bio-based products.

3.5.1 ISCC Organization and Stakeholders

ISCC e.V. membership is voluntary, i.e. users which apply for ISCC certification do not have to become an ISCC member. The ISCC System GmbH is responsible for the day to day business ranging from registration of new system users, verification of certificates, training of auditors, quality management to developing the system further in order to better respond to user needs.

Currently ISCC cooperates with 23 certification bodies and more than 800 auditors and professionals have been trained during the last few years. The ISCC System GmbH also operates an integrity management system where independent auditors perform surveillance audits of already certified system users. Selection either takes place on a random basis or when evidence was provided that ISCC requirements might have been violated by users or certification bodies. During the years of operation this governance structure and respective measures and sanctions have strengthened the ISCC brand significantly in terms of credibility and reliability.

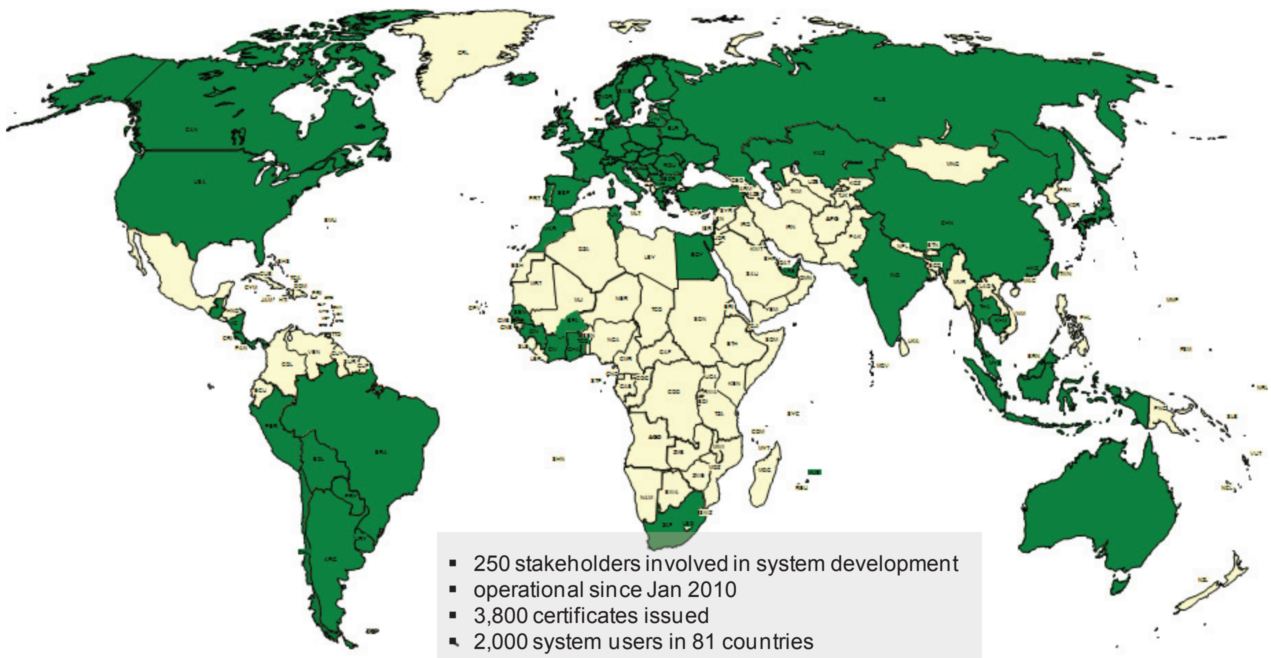


Figure 15 – ISCC footprint (in green)

3.5.2 Certification Scope

Biofuels which are brought to market within in the European Union must comply with the requirements of the Renewable Energy Directive 2009/28/EC (RED). The RED requirements embrace protection of environmentally sensitive areas, greenhouse gas (GHG) emission savings of 35 percent and traceability and mass balance within the supply chain. Compliance with the RED requirements can be demonstrated through one of several voluntary certification systems recognized by the European Commission, including ISCC. Within ISCC the entire supply chain from agricultural level down to the "quota obligated party" is audited by independent certification bodies. Positive audit results of the individual element of the supply chain qualify for an ISCC certificate which is valid for twelve months. This enables the certificate holder to participate in a sustainable supply chain and to take in and to pass on sustainable products and issue respective sustainability declarations.

3

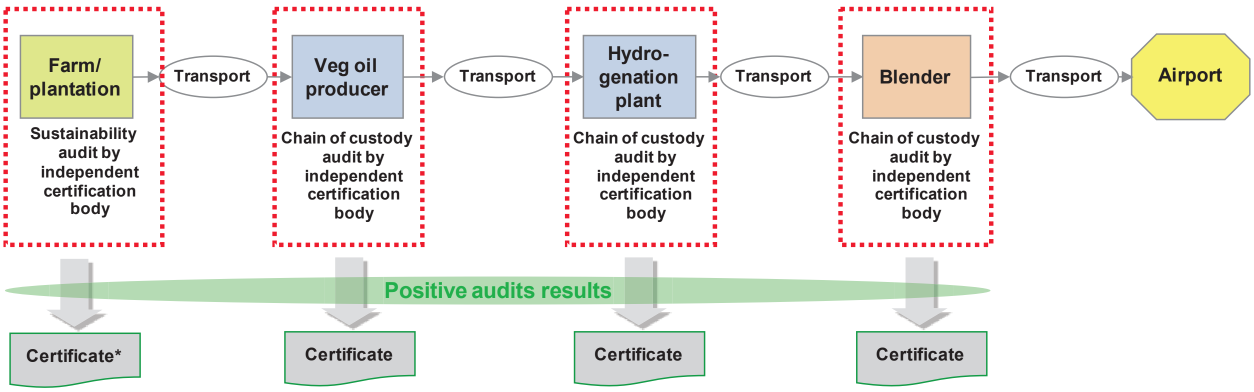


Figure 16 – Illustrative example of a sustainable supply chain

Generally ISCC distinguishes between two types of audits. One is the sustainability audit on farms or plantations which includes a wide range of ecological, economic and social sustainability criteria and farm-related GHG emissions. The other, a chain of custody audit, covers traceability of the product, GHG emissions and the mass balance calculation for the operational unit (e.g. the hydrogenation plant in Figure 16).

ISCC audits are on-site audits. For conversion units like oil mills, hydrogenation plants, biodiesel plants or refineries, every unit must be audited and receives an individual certificate. Farms and plantations can be audited on a sample basis. In the example above the first gathering point is the oil mill (vegetable oil producer). However, it is also possible for farms or plantations to get audited individually on voluntary basis.

ISCC audit requirements do not differ for bioethanol, biodiesel or biojet fuel; the audit process and criteria are generally the same. ISCC is also recognized for the certification of waste and residue-based biofuels. In this case, the same principles are applied, with the difference that the originator of waste is not subject to an audit and the waste or residue material is assigned zero GHG emissions.

ISCC system users have the choice whether they would like to perform an individual GHG calculation or use a default value as listed in the RED. Current default values for most biofuels are sufficient to meet the GHG emissions saving target of 35 percent. However, the default values will not be sufficient for palm-based biodiesel (without methane capturing technology) and soy-based biodiesel. In these cases individual GHG calculations are required. It is also important to note that not every certification system recognized by the European Commission is eligible for individual GHG calculations. User of soy and palm based biofuels fuels therefore need to be certified under systems that are recognized for individual GHG calculation, such as ISCC. This issue becomes even more important as the RED targets for GHG emission savings will increase to 50 and 60 percent in the coming years. By then, many of the conventional biofuels will require individual GHG calculations in order to meet these targets.

3

ISCC sustainability criteria go beyond the RED requirements, which mainly focus on land use change after the year 2008. The ISCC sustainability requirements also cover the protection of areas with high biodiversity value, areas with high carbon stock and peat land as well as land use change of protected areas after January 2008. In addition to the land use requirements, farms and plantations must comply with good agricultural practices, measures for environmental protection, provide safe working conditions and social sustainability as well as compliance with laws and regulations. Further details on the individual sustainability criteria can be found within the ISCC document 202[11].

11. http://www.iscc-system.org/en/certification-process/certification/basics/

4. Economics

4.1 Chapter Summary

staza

Biojet pathways face significant cost challenges. Depending on the details of the particular pathway, the price premium of the biofuel over conventional jet fuel could be the result of high feedstock costs, high capital expenses, or some combination of the two. There are incentive structures in place in certain countries which help reduce these additional cost burdens for the fuel producer. Energy technology is expected to improve over time due to market competition, experience, and innovation, which should drive down fuel production costs, while conventional jet fuel prices are expected to increase.

IATA gratefully acknowledges Mitch R. Withers, Matthew N. Pearlson, and Robert Malina of the Massachusetts Institute of Technology for their contributions to this chapter.

4.2 Conventional Jet Fuel Price Development and Incentives for Alternative Fuels as Points of reference

Alternative aviation fuels compete with conventional jet fuel from petroleum. Airlines operate in a highly competitive, low-margin market and can be expected to refrain from large-scale usage of alternative fuels if they are not cost-competitive with the conventional counterpart. This does not necessarily imply that these fuels need to be competitive on their own in the short term, since there are policies in place that give incentives to produce and use alternative aviation fuels. One example is the revised Renewable Fuels Standard (RFS2) described in Chapter 3 of this report. Although the renewable volume obligations (RVO) specified by RFS2 do not require production of renewable jet fuel, it can qualify for a renewable identification number (RIN)[12], which can be traded and used by obligated parties to satisfy renewable fuel mandates. At current prices, RINs can offset the cost differential between alternative and conventional jet fuel by $0.26/L ($1/gal). However, because separating jet fuel from diesel fuel requires additional processing, RFS2 is more likely to incentivize biomass-based diesel production over biojet[13].

uzdržati se

While there is considerable uncertainty about the future price of conventional jet fuel, prices are generally expected to increase in the coming decades due to increased global demand for crude. The U.S. Energy Information Administration has published past and current jet fuel prices in the United States as well as price projections for jet fuel for the next three decades (see Figure 17)[14]. As shown in the figure, baseline EIA projections suggest that the price of jet fuel will continue to increase steadily over the next thirty years. In the high price scenario jet fuel sells at around $1.59/L ($6/gal, all prices in 2012 U.S. dollars), in the low scenario it sells at around $0.53/L ($2/gal). The average spot price of jet fuel for 2013 (January-September) is $0.75/L ($2.82/gal).

12. U.S Environmental Protection Agency, Renewable Fuels Compliance Help http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-aq.htm#1
13. Winchester N, McConnachie D, Wollersheim C, (2013): Economic and Emissions Impacts of Renewable Fuel Goals for Aviation in the US, in: Transportation Research Part A, forthcoming.
14. U.S. Energy Information Administration, (2012): Annual Energy Outlook 2012.

4

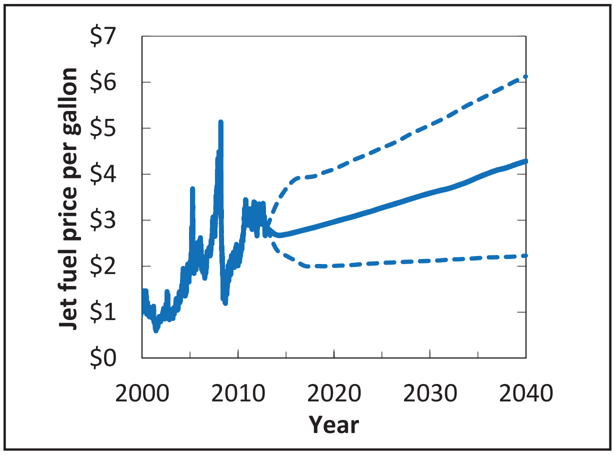


Figure 17 – EIA price projections for jet fuel in the United States from 2012 Annual Energy Outlook. All values in year 2012 U.S. dollars.

4.3 Actual Purchase Prices

Alternative jet fuels are currently produced in small quantities compared to both petroleum jet and corn ethanol: Over the last 5 years, the U.S. military has purchased 1.9 million gallons of jet fuel through its procurement agency DLA Energy, which gives reliable data regarding the actual purchase prices of biofuels. These are shown in Table 2.

Pathway	Quantity in L (gal)	Total Cost	Average Cost $/L ($/gal)	Min $/L ($/gal)	Max $/L ($/gal)	Contracts (Suppliers)
HRJ/HEFA[15]	4,108,428 (1,085,450)	$41,534,620	10.11 (38.26)	7.07 (26.75)	39.37 (149.00)	12 (4)
FT[16]	2,763,050 (730,000)	$2,745,650	0.99 (3.76)	0.90 (3.41)	1.85 (7.00)	4 (3)
ATJ[17]	352,005 (93,000)	$5,487,000	15.59 (59.00)	15.59 (59.00)	15.59 (59.00)	4 (1)
DSH[18]	162,755 (43,000)	$1,106,390	6.80 (25.73)	6.80 (25.73)	6.80 (25.73)	4 (1)
HDC-D[19]	24,603 (6,500)	$57,525	2.34 (8.85)	2.34 (8.85)	2.34 (8.85)	2 (1)

Table 2 – Alternative fuel purchases made by the U.S. Department of Defense shown by fuel pathway, from 2007 to November 2012. Source: DLA Energy. Some prices may be artificially high, as contracts may also include R&D costs in addition to production costs. Note 1 gal = 3.785 L

HRJ/HEFA fuels are produced by hydroprocessing esters and fatty acids, such as edible (soybean, canola) and non-edible (camelina, jatropha) plant oils, algal oil, yellow grease (rendered used cooking oil), and tallow (rendered animal fat). The maximum price of $149/gal corresponds to fuel produced from algal oil, the economics of which have been discussed in previous editions of this report[20]. Between 2007 and 2012, the U.S. military procured 1 million gallons of HRJ/HEFA jet fuel at an average price of $10.04/L ($38/gal).

Fischer-Tropsch (FT) jet fuel is derived from gasification of carbonaceous feedstocks and the subsequent conversion and upgrading of synthesis gas to liquid fuels via a catalytic process. The U.S. military bought 730,000 gallons of FT jet fuel at an average price of $0.99/L ($3.76/gal), though not from renewable feedstocks. The cost difference to conventional jet fuel in DLA's procurement is the lowest for FT jet fuel.

15. **Hydroprocessed Renewable Jet/Hydroprocessed Esters and Fatty Acids** from camelina, algal oil, used cooking oil, tallow
16. **Fischer-Tropsch Jet Fuel** from natural gas, coal
17. **Alcohol to Jet** from alcohols
18. **Direct Sugar to Hydrocarbon** from sugar fermentation
19. **Hydrotreated Depolymerized Cellulosic Diesel** from lignocellulosic biomass
20. International Air Transport Association, (2012): IATA 2012 Report on Alternative Fuels, Montreal – Geneva.

Alcohol-to-jet (ATJ) processes use commodity alcohols (ethanol, butanol) as platform molecules for oligomerization or catalytic synthesis reactions. Alcohols can also be produced from biomass via advanced fermentation processes. So far, less than 378,500 L (100,000 gal) of ATJ were purchased by the U.S military from a single supplier at a price of $15.59/L ($59/gal).

Direct sugar-to-hydrocarbon (DSH) pathways rely on genetically-engineered microorganisms that digest sugars and produce hydrocarbon fuel components (as opposed to alcohols, which are upgraded in a separate process). DLA Energy procured 163,755 L (43,000 gal) of DSH jet fuel at a price of $6.80/L ($25.73/gal).

Hydrotreated Depolymerized Cellulosic Diesel (HDC-D) fuels are produced by hydrous pyrolysis of biomass feedstocks followed by hydroprocessing of the pyrolysis oil. So far, only 24,600 L (6,500 gal) of HDC-D fuel have been purchased, at a price of $2.34/L ($8.85/gal).

For commercial aviation, there is limited data available on costs of alternative fuel purchase agreements. In 2011, Alaska Airlines purchased 105,980 L (28,000 gal) of renewable jet fuel from used cooking oil at an average price of $4.49/L ($17/gal)[21].

In mid-2013, United Airlines entered into a purchase agreement for 56.8 million L (15 million gal) of jet fuel from agricultural waste and non-edible oils. There is no data publicly accessible on the purchase price of this renewable fuel. However, both parties state that the fuel will be sold at prices competitive with conventional jet fuel, which is likely inclusive of monetary incentives through RFS2[22].

4.4 Theoretical Purchase Prices

Competitive markets should lead to selling prices decreasing over time. This is especially the case for new technologies where significant cost reductions can be achieved through learning. Among the alternative fuel technologies considered herein, FT is the most mature, having been used for decades with coal (Sasol) and for several years with natural gas (Shell). Biomass gasification is largely based on mature coal gasification technology, but additional biomass-specific treatment methods are less mature. Learning effects can be significant, especially in the early years of technology deployment. In a study conducted for the U.S. Department of Energy, for example, it was estimated that costs for HDC-D should decrease by ~50% over the course of five years due to improvement in achieved process efficiencies[23].

Theoretical purchase prices for mature industries have been calculated in literature using minimum selling price (MSP) approaches[24]. These prices are meant to be representative for fuels which are produced in several refineries using a certain technology, with lower contingency, start-up costs and risk premiums than first of its kind plants. These "N-th plant" studies rely on technoeconomic analyses to estimate capital expenses and operating costs for fuel production facilities. Plant economics can be assessed by employing a discounted cash flow rate of return (DCFROR) model, which is standard practice for chemical engineering cost analysis. These models capture the net present value of discounted cash flows related to loan interest payments, direct and variable operating costs, sales revenues, and taxes. Other financial parameters are included as necessary, such as construction time, production ramp up, depreciation, and inflation to model various production scenarios. The minimum selling price is determined from this information and represents the price at which the fuel must be sold in order for the project to achieve a specified internal rate of return (with a net present value of zero). If multiple products are produced, the prices of the co-products are either held constant at market value (isolated cost burden) or varied relative to the jet fuel price (distributed cost burden).

Table 3 gives price estimates for HRJ/HEFA, FT, and ATJ fuel pathways. Price estimates are based on current technologies, and major technological advancements are not factored in. The MSP is a plant gate price and excludes transport, taxes, and retail markup. Baseline scenarios reflect average efficiencies and

21. http://seattletimes.com/html/businesstechnology/2016719598_alaska09.html
22. http://www.prnewswire.com/news-releases/united-airlines-and-altair-fuels-to-bring-commercial-scale-cost-competitive-biofuels-to-aviation-industry-210073841.html
23. Jones S, Male J, (2012): Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: 2011 State of Technology and Projections to 2017, Pacific Northwest National Laboratory, report PNNL-22133.
24. Pearlson M, Wollersheim C, Hileman J, (2013): A techno-economic review of hydroprocessed renewable esters and fatty acids for jet fuel production, Biofuels, Bioproducts and Biorefining, Vol. 7, No. 1, pp. 89–96.

intermediate plant sizes, while low and high scenarios are determined by varying feedstock costs, plant sizes, efficiencies, and capital expenses within reasonable bounds. The estimates show that HRJ/HEFA, FT jet from biomass and ATJ fuels are expected to significantly decrease in cost compared to prices currently being paid. Current coal and natural gas FT purchase prices are close to the estimated MSPs already due to the maturity of FT technology. Based on N-th plant estimates, all fuels considered can potentially become cost competitive to conventional jet fuel. It should be noted the input experience cost curve assumptions used and developed my MIT are essential for achieving the forecast prices in table 3.

Pathway	Feedstock	Minimum selling price estimate (MSP)		
		Low ($/L)	Baseline ($/L)	High ($/L)
HRJ/HEFA	Soybean oil	1.16	1.20	1.27
	Tallow	1.05	1.09	1.16
	Yellow grease	0.88	0.92	0.99
FT	Natural gas	0.77	1.03	1.28
	Coal	0.87	1.17	1.97
	Switchgrass	1.42	1.97	2.52
ATJ	Sugar cane	0.61	1.37	2.34
	Corn grain	0.71	1.57	3.65
	Switchgrass	1.09	2.01	6.28

Table 3 – Theoretical fuel prices for alternative jet fuels from different feedstocks and pathways.
Sources: Footnote 24 and ongoing MIT research.

However, it should be emphasized that these price estimations represent future steady-state values. We note again, that aviation biofuel markets are not fully developed yet and that current production costs would be significantly higher than steady-state costs. Furthermore, even small price premiums over jet fuel have a large financial impact. For example, an increase in the jet fuel price of just $0.10 per gallon adds $7 billion globally to the airline industry fuel bill each year.

4.5 Cost Drivers

HRJ/HEFA fuel prices are driven by high feedstock costs. The feedstocks shown in Table 3 (soybean oil, tallow, and yellow grease) are often more expensive in their raw forms than conventional jet fuel. Soybean oil is more expensive but more readily available than tallow or used cooking oil, which are available only in small quantities, limiting the scalability of commercial production. Using USDA data on feedstock availability it can be shown that up to 500 million gallons of HEFA jet fuel, 240 million gallons of HEFA diesel and 80 million gallons of naphtha could be produced annually if all tallow and yellow grease rendered in the US were used. This would account for ~3% of current jet fuel demand in the US.

It is well understood that capital expenses are the main drivers for Fischer-Tropsch synthesis[25]. Specifically, the gasifier, air separation unit, and FT reactor are the most expensive components. One advantage of FT synthesis is its ability to use syngas derived from a variety of inexpensive feedstocks.

25. Carter N, Stratton R, Bredehoeft M, (2011): Energy and Environmental Viability of Select Alternative Jet Fuel Pathways, AIAA 2011-5968, 47th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, San Diego, CA, August 2011.

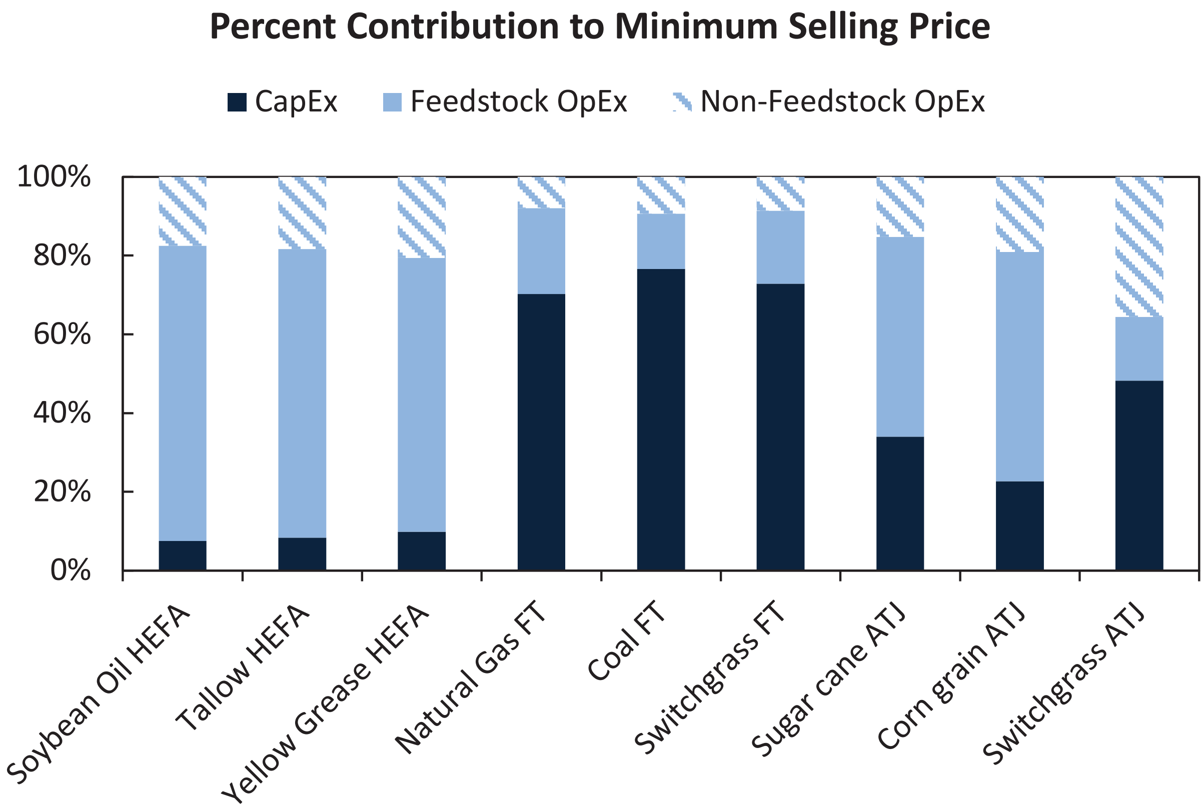


Figure 18 – Percent contributions of operating and capital expenses to minimum selling prices.
Sources: Footnote 24 and ongoing MIT research.

ATJ pathways have higher relative capital costs than HEFA fuel pathways, but still lower than FT. However, the sugar-yielding feedstocks considered are less expensive than oily feedstocks, especially in the case of sugars derived from lignocellulosic biomass such as switchgrass.

4.6 Future Cost Reductions

Even in mature industries, there is continued learning and technological improvement. There have been recent advancements in proprietary technologies (e.g. Sundrop, Primus Green Energy) that aim to reduce the high capital expenses related to biomass gasification and natural gas reforming. Moreover, some companies are taking advantage of low-cost natural gas as a process fuel and a feedstock (H2 source) to offset the cost of biomass. Disruptive technologies, such as genetically-engineered microorganisms and plant species, may generate new pathways for biofuel production, improve process efficiencies, and decrease feedstock costs.

As has been shown above, feedstock costs play a critical role for the economics of biofuels, especially in the case of HEFA jet fuel. Waste oils and animal fats are cheaper feedstocks that lead to relatively lower fuel prices but are limited in availability. Alternative low-cost feedstocks for HEFA processes include oilseed crops grown in rotation with other crops on land that otherwise would have been left fallow, thereby increasing the efficiency of land use. Two promising rotation crops in the US include pennycress and camelina. As long as oilseed rotation crops do not impact pest control, moisture, and nutrient content of the soil in comparison to fallow land, there are no opportunity costs associated with using this land for these crops. Costs are only incurred during the actual cultivation. In a recent study, Winchester et al. (2013) estimate that HEFA jet fuel from rotation crops in the U.S. such as camelina and pennycress could be produced at around \$0.98/L (\$3.70/gal)[26]. This paper also states that these rotation crops could potentially be grown on ~43 million acres in the U.S. per year, which could yield up to 12. 1 billion L (3.2 billion gal) of renewable jet fuel per year.

26. Winchester N, McConnachie D, Wollersheim C, (2013): Economic and Emissions Impacts of Renewable Fuel Goals for Aviation in the US, in: Transportation Research Part A, forthcoming.

Another significant avenue for cost reduction is the possibility of producing high value chemicals along with jet fuel. This can be achieved via different biochemical and thermochemical routes. For example, aqueous phase processing of lignocellulosic feedstocks can produce furfural, hydroxymethylfurfural (HMF), and acetic acid in addition to fuel products. These high value chemicals can be sold at market prices to internally subsidize the cost of the biofuels. Ongoing research at MIT on this pathway indicates that having biofuels as a by-product of chemical production has been shown to reduce the MSP of the biofuel by 77% compared to a case in which the biorefinery is set up to maximize fuel output. This would make the fuel cost-competitive with conventional jet fuel, with or without RINs. However, limitations in terms of the size of the chemical markets need to be taken into account, since flooding of these markets with renewable products will drive the price down, therefore reducing the value of the non-fuel part of the refinery output and driving up the required selling price of renewable jet fuel. Therefore, the bigger the market for the renewable chemicals being produced, the smaller the price effect of additional production and consequently, the bigger the benefit from co-producing fuels and chemicals.

4.7 Concluding Remarks

Cost challenges for several biojet pathways have been examined, and price premiums have been found to originate from different sources depending on the fuel pathway. Incentive structures and technological improvements can reduce these cost burdens. As a result, aviation biofuels may have the potential to become cost competitive with conventional jet fuel in the near future.

5. National and International Biojet Support Programs

5

5.1 Chapter Summary

This chapter provides description of recent biofuel developments from state and industry stakeholders.

- In the US, the Defence Logistics Agency are involved in numerous initiative supporting the certification and commercialization of alternative aviation fuels and the provision of technical and contracting support in an Advanced Drop-In Biofuel Production Project.
- The EU's Biofuels Flightpath initiative's primary aim is to mobilize all stakeholders, ensuring that two million tons of sustainable biofuels are used by the EU aviation sector by 2020.
- In Spain, the ITAKA (Initiative Towards SustAinable Kerosene for Aviation), project integrates a full production and use value chain.
- Swedish Biofuels AB will coordinate an international consortium over the next five years with the goal of producing paraffinic biofuels for use in aviation.
- In Italy, the BIOREFLY project will construct a paraffinic aviation fuel plant at industrial scale completing the lignocelluosic-to-bioethanol production chain through the chemical valorization of secondary streams.
- In Germany, the year 2013 for aireg was marked by the initiation of concrete projects to support aireg's strategy for a prompt market introduction of alternative aviation fuels.
- The Sustainable Aviation Biofuels for Brazil published "Flightpath to Aviation Biofuels in Brazil: Action Plan" highlighting the gaps and opportunities for the implementation of a new sustainable aviation biofuels industry.

IATA gratefully acknowledges Pam Serino (DLA), Kyriakos Maniatis (EC), Stefano Pescarolo (Biochemtex), Alexander Zschocke (DLH), Cesar Velarde Catolfi-Salvoni (ITAKA), Angelica Hull (Swedish Biofuels), Marcelo de Freitas Goncalves (Embraer) and Lukas Rohlder (aireg) for their contributions to this chapter.

5.2 US Defence Logistics Agency (DLA) Energy Biofuels Initiatives

5.2.1 Overview

The United States Military Services along with DLA Energy are currently involved in multiple initiatives supporting the certification and commercialization of alternative aviation fuels. Investments in alternative aviation fuels aim to improve the reliability of the Department of Defense's overall fuel supply in terms of resilience against supply disruptions, reduction in the impacts of petroleum price volatility and increased options for fuel supply sources.

5.2.2 Military Application

DLA Energy has supported the services in their alternative fuel certification and approval efforts through numerous procurement actions. During 2007 and 2008 DLA Energy awarded three contracts for 730,000 gallons of Fischer Tropsch aviation fuels derived from both coal and natural gas feedstocks, fulfilling the quantities required by the Air Force for testing and certification. In 2009 and 2010 DLA Energy established seven contracts totaling 800,000 gallons for delivery of hydrotreated renewable (HR) JP-8, JP-5 and F-76 for Air Force, Army and Navy certifications programs. These fuels were derived from a variety of feedstocks including camelina, tallow and algal oil. Currently undergoing certification is fuel derived from the dehydration and oligomerization of alcohols. Over the past couple years DLA Energy has awarded five contracts for alcohol to jet (ATJ) JP-8 and JP-5 for a total of 73,000 gallons. Lastly, DLA Energy has supported other Navy certification efforts by awarding contracts for alternative marine fuel F-76 derived from direct sugar to hydrocarbon (43,000 gallons) and hydroprocessed depolymerized cellulosic diesel pathways. While these alternative F-76 fuels are not aviation fuels, the conversion technologies used to produce them are currently moving through the ASTM International certification and approval process for inclusion in the ASTM D7566 specification for synthesized hydrocarbons.

5.2.3 Promoting Commercialization

For the next step, DLA Energy is focused on bridging the gap between certification and commercial scale production by supporting a variety of demonstration programs and initiatives through partnerships with other government organizations and industry. These efforts help promote a competitive industry, potentially providing the military a supplier base capable of producing operational volumes in order to meet future goals. These include the Air Force's goal to be prepared to cost competitively purchase 50 percent of its domestic aviation fuel requirement from an alternative source by 2016 and the Navy's goal to satisfy 50 percent of all energy requirements with alternative sources by 2020.

In addition, DLA Energy is currently involved in the Green Initiative for Fuels Transition Pacific (GIFTPAC), which is a working group of over 30 member organizations and commands, co-led by United States Pacific Command and the United States Department of the Navy. The group aims to purchase and use cost-competitive domestically produced advanced biofuels by 2018 to displace at least 25 percent of the fuel used by the Department of Defense in Hawaii. The estimated requirements for aviation and marine diesel fuels in Hawaii are 78,550,000 gallons of JP8, 7,180,000 gallons of JP5, and 42,250,000 gallons of F76.

Lastly, DLA Energy is providing technical and contracting support in an Advanced Drop-In Biofuel Production Project being established under the authority of Title III of the 1950 Defense Production Act (DPA). DPA Title III allows the Government to provide appropriate incentives, including funding, to enhance the production capabilities of domestic industrial resources to ensure Government access to critical technology items. The Government intends to form an Integrated Biofuels Production Enterprise (IBPE) comprised of partnerships with commercial facilities capable of producing drop-in replacement biofuels certified to be military specification JP8, JP5 and/or F76 blend equivalents. Up to five bio-refineries, each capable of producing in excess of 10 million gallons of advanced biofuels by 2016, would result from the initiative. In May 2013, three contracts totaling $16 million were awarded to Emerald Biofuels, Natures BioReserve and Fulcrum Biofuels for the initial design phase of the program. A second phase, which would be funded out of FY 2013 and later years funding, would award up to $180 million in additional contracts to accelerate the construction of one or more bio-refineries to meet the Navy's Great Green Fleet plans.

Economics and environmental Sustainability challenges, such as greenhouse gas emissions, water use, land use, particulate emissions, nutrient depletion and competition with food have also come to the forefront of the biofuels discussion. The relevant regulation requires the life cycle greenhouse gas emissions of government-procured alternative fuels, other than for R & D testing, be less than or equal to that of conventional petroleum. Currently, DLA Energy is working with other government agencies, academia and commercial industry through the Commercial Aviation Alternative Fuels Initiative (CAAFI) Environmental group, to develop guidance and compliance mechanisms for lifecycle greenhouse gas emission regulations like section 526 of the EISA.

5.2.4 Research and Development

To further expand previous work regarding environment and economics, DLA Energy along with the Federal Aviation Administration and the Air Force Research Lab through the FAA's **Partnership** for AiR Transportation Noise and Emissions Reduction (PARTNER) program continue to fund research and development into the areas of lifecycle greenhouse gas analysis for which data generated will be used to further modify the GREET model and also to assist the U.S. Environmental Protections Agency in qualifying alternative fuel pathways under the Renewable Fuels Standard program; techno-economic analysis to provide insight into the commercial viability of various alternative fuel feedstock sources and conversion technologies; water usage to investigate impacts alternative aviation fuel pathways would have on regional water resources; and long term scenario analysis to assess what alternative aviation fuel feedstocks and pathways would be optimal for achieving various agency goals. Conversion pathways under investigation include alcohol to jet, direct conversion of sugar to jet through microbial fermentation, pyrolysis, catalytic hydrothermolysis, algae to jet, and aqueous phase reformation.

Pursuant to the concerns of biofuel feedstock availability, DLA has commissioned a study that is assessing the factors related to their complete logistics chains (including production, harvesting/recovery, oil extraction and transportation to a refining/processing location). The goal of the study is to develop sustainability metrics for domestically produced, next generation (non-food related) feedstocks to allow DLA Energy to establish a foundation for assessing the further development of feedstocks and feedstock processing. The metrics will be used to evaluate existing feedstocks to assist in determining which have the most viable sustainability in order to enhance DoD acquisitions of biofuels; identify and evaluate new feedstocks; and identify areas in renewable fuel production (feedstock growth, oil extraction, oil processing etc.) in which improvements can be made. The metrics address such elements as land requirements; water requirements; economic viability; greenhouse gas/carbon and other emissions; current feedstock oil extraction methods/capabilities; and environmental impacts and related concerns. The study, initiated in 2011, was completed in early 2013; the architecture developed by the project contractor, LMI Government Consulting, addresses the sustainability of accepted biofuel production pathways, specific to feedstocks used, by evaluating the risks of a production enterprise to the existing Class III B supply chain into which biofuels would be incorporated. Using technical indicator sheets developed by LMI which address key measurable metrics, a total risk assessment of a production enterprise can be determined, and with it an acceptability rating of contracting for fuel from the enterprise, particularly for long term contracts (which many start up enterprises desire in order to justify initial capital requirements).

Through partnerships across the biofuels stakeholder value chain, DLA Energy aims to assist the alternative fuels industry to grow into a strong supplier base. With such a base, DLA Energy could then continue doing what we have done for decades: buying fuel for its customers, no matter how the product may have changed.

5.3 The EU Biofuels Flightpath Initiative

5.3.1 Background[27]

The Biofuels FlightPath is a private-public initiative amongst the EU aviation sector, leading companies developing technologies for advanced and sustainable biofuels and the European Commission. Its primary aim is to mobilize all stakeholders, ensuring that two million tons of sustainable biofuels are used by the EU aviation sector by 2020. Five organizations from the aviation sector, five leading advanced biofuel organizations and the European Commission[28] comprise the core team of the Biofuels Flightpath that lead all actions related to it. This ambitious but achievable target was set on 22 June 2011 during the International Airshow at le Bourget, Paris. This exciting new industry wide initiative aims to speed up the deployment and commercialization of sustainable aviation biofuels in Europe.

5.3.2 Objectives

The following points outline the Biofuels Flightpath objectives:

1. Facilitate the development of standards for drop-in biofuels and their certification for use in commercial aircraft
2. Work together with the full supply chain to further develop worldwide accepted sustainability certification frameworks
3. Agree on biofuel off-take arrangements over a defined period of time and at a reasonable cost
4. Promote appropriate public and private actions to ensure the market uptake of paraffinic biofuels by the aviation sector
5. Establish financing structures to facilitate the realization of second generation and advanced biofuel projects
6. Accelerate targeted research and innovation for advanced biofuel technologies including algae
7. Take concrete actions to inform the European citizen of the benefits of replacing kerosene by certified sustainable biofuels

27. The background and objectives were first presented in IATA's 2012 Report on Alternative Fuels.

28. Airbus, Lufthansa, Air France/KLM, British Airways, Neste Oil, Biomass Technology Group, UOP, Chemtex Italia, UPM and the Directorate General for Energy

5.3.3 Flightpath 2020 Workshop

The main rationale behind the use of bio kerosene is the reduction of CO_2-emissions, plus having an alternative to fossil fuels. However, a switch to biofuels should not result in an increase in harmful emissions other than CO_2. For this purpose, a Flightpath 2020 workshop on non-CO_2 emissions was held in Brussels on 25th April 2013, investigating the relationship between fuel composition and emissions.

The main workshop results were:

- The main non-CO_2 environmental effects related to the fuel composition are ultrafine particles, NOx and induced contrails.
- Ultrafine particles are a ground issue directly effecting human health. In general the effects of ultrafine emissions from aircraft are dwarfed by the ultrafine particles emissions from road transport, but for locations directly on the airports high concentrations are possible, potentially creating a workplace issue.
- NOx emissions are primarily a low altitude issue. NOx is potentially dangerous to human health, both directly and via low-altitude ozone formation. There also is a higher altitude effect. NOx is not itself a greenhouse gas, but is causing ozone production with greenhouse impacts. However the effect is more complex as NOx reduces methane, which is another greenhouse gas.
- Contrails are a high altitude issue with a potential climate impact. Contrails can contribute to greenhouse effects by blocking the radiation of energy from earth back into space, both directly and by inducing cirrus cloud formation. The radiative factor of contrails is however still subject to high uncertainty levels.
- The evidence so far for the already certified Fischer-Tropsch (FT) and Hydroprocessed Esters and Fatty Acids (HEFA) drop-in biofuels is that they can have a benign influence on ultrafine particles and on contrail-inducing emissions, as they have far less aromatics and far less impurities. This will however not necessarily be true for other production pathways still undergoing certification, some of which also include the formation of aromatics. Effects of FT and HEFA fuels on NOx are less pronounced.
- There is currently a practical limit to the extent to which FT and HEFA fuels can reduce aromatics content since fuel specifications require a minimum aromatics content of 8% for any blend of conventional and synthetic kerosene. This requirement exists because aromatics are required for seal swell, keeping fuel seals and valves tight. However, the requirement is conservative, and will need refinement in the future.
- The properties of any blend of conventional and synthetic kerosene will depend not only on the synthetic kerosene, but also on the properties of the conventional kerosene, which are quite heterogeneous. In some cases, the relationship between the properties of the fuels and the properties of the blend is linear and well explored, but in other cases it is non-linear and / or little researched. Likewise, the relationship between a parameter like aromatics content and soot-formation behavior is not necessarily straightforward, but depends on fuel composition.

The following research requirements were identified:

- Research into contrail impact on cloud formation, and into the radiative factor of contrails needs to be reinforced in order to get a scientific consensus in the near future. Particular research needs are improved model building, modeling of natural ice clouds and verification of theoretical models by in flight measurements.
- The relationship between fuel properties and emissions has so far only been explored for individual cases, typically looking only at one given engine. This relationship should be systema-tically explored covering all common engine families. This will be even more important for novel biofuels containing synthetic aromatics.
- The relationship between aromatics composition and seal swell needs to be explored further, in order to identify the absolute minimum amount of aromatics needed. At the same time, the relationship between aromatics composition, sooting tendencies and interrelation with other fuel properties needs to be researched for the common engine families.
- Research is required to understand the chemical composition impact on blend properties, specifically for those parameters where blend relationships are non-linear and complex. This will require significant work.
- A worldwide inventory of fuel properties should be taken, to understand what kind of conventional kerosenes are actually available for blending.

In conclusion, ultrafine particles affect human health at ground level, while NOx (an issue at low attitude) and contrails (an issue at high altitude) may have effects on climate change. Bio-kerosene may ameliorate some of these effects. Significant research efforts are needed to better understand the issues related to non CO_2 emissions.

5.3.4 Flightpath Blending Study

In February 2013 a consortium consisting of Lufthansa and WIWeB (the German Armed Forces Research Institute for Materials, Fuels and Lubricants) signed a contract[29] with the European Commission to conduct a study into the blending behavior of biofuels with kerosene. This study, financed by the Commission as part of the Flightpath 2020 initiative, will investigate how the properties of a biofuel blend are affected by the properties of both the conventional kerosene and the biofuel with emphasis on blends above 50%.

The rationale behind this study is the recognition that the properties of conventional kerosene are highly variable, and in practice constitute a limiting factor for blending ratios. In principle, blending ratios of up to 50% are certified for HEFA and FT fuels, and ASTM as the certifying body has expres-sed its intention to relax this restriction in the future. However, the blend needs to meet the target parameters of the conventional kerosene specification, and this often limits achievable blending ratios well to below 50%, and will become the sole constraint once the 50% limit is removed by ASTM. It therefore is important to know which types of conventional fuel are suitable for high blending ratios, and which are not. The study will also explore to which extent the achievable blending ratio can be increased by adding aromatics.

The study focus will be on lab analysis, but a number of engine rig runs for emission measurements are also planned. It was initially expected that the study would only cover HEFA fuels, due to a lack of availability of other fuels. However, recent progress with other production pathways means that other fuels will also be included in the study.

It is expected that the study will be finished in the second half of 2014, with the results to be published thereafter.

5.4 The European Commission's Seventh Framework Programme

Funding programmes created by the European Union in order to support and encourage research in the European Research Area (ERA) are called Framework Programmes for Research and Technological Development, also called Framework Programmes or abbreviated FP1 through FP8. FP7 covers the period from 2007 to 2013. The European Commission's Community Research & Development Information Service describes FP7 as follows:

> *Knowledge lies at the heart of the European Union's Lisbon Strategy to become the "most dynamic competitive knowledge-based economy in the world". The 'knowledge triangle' – research, education and innovation – is a core factor in European efforts to meet the ambitious Lisbon goals. Numerous programmes, initiatives and support measures are carried out at EU level in support of knowledge.*
>
> *The Seventh Framework Programme (FP7) bundles all research-related EU initiatives together under a common roof playing a crucial role in reaching the goals of growth, competitiveness and employment; along with a new Competitiveness and Innovation Framework Programme (CIP), Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness. It is also a key pillar for the European Research Area (ERA).*
>
> *The broad objectives of FP7 have been grouped into four categories: Cooperation, Ideas, People and Capacities. For each type of objective, there is a specific programme corresponding to the main areas of EU research policy. All specific programmes work together to promote and encourage the creation of European poles of (scientific) excellence.*

What follows is the description of four aviation biofuel initiatives resulting from FP7: ITAKA, Swedish Biofuels, BIOREFLY and the Spanish Bioqueroseno Initiative.

29. High Biofuels Blends in Aviation, Tender Contract ENER/C2/2012/420-1/SI2.643219

5.4.1 The EU ITAKA Project

SENASA and 12 partners from 9 different countries are developing the project ITAKA (Initiative Towards SustAinable Kerosene for Aviation), integrating a full production and use value chain.

The project links supply and demand by establishing a relationship between the feedstock growers and producers, biofuels refiners, distributors and airlines. In parallel, the project investigates the sustainability of all processes according to international standards (Roundtable for Sustainable Biomaterials EU-RED).

5.4.1.1 ITAKA Objectives

The overall objective of ITAKA in the field of Research and Innovation is to develop a full value-chain in Europe to produce sustainable Synthetic Paraffinic Kerosene (SPK) at large scale enough to allow testing its use in existing logistic systems and in normal flight operations in Europe. ITAKA will assess its sustainability, economic competitiveness and technology readiness, in order to identify and address barriers to innovation.

In order to achieve this in the most efficient way ITAKA will has identified camelina oil as a possible feedstock that can be produced in a timely and sustainable manner and in adequate quantity within Europe. In particular, the agricultural model explored in Spain is expected to demonstrate its minimum potential Indirect Land-Use Impacts (ILUC) as it is produced in otherwise unproductive fallow land in low-quality agricultural lands.

Being the first of its kind collaborative project in the EU, ITAKA will address challenges in two main areas of Research and Technology Development (RTD):

- Development of commercial scale production and study implications of large-scale use.
- Research on sustainability, economic competitiveness and technology readiness.

Beyond this main technological and research objective, ITAKA also aims to contribute to the achievement of a further EU objective: the need to coordinate efforts and complementarities among European Initiatives on sustainable aviation fuels, highlighted in the Flightpath section above, and identified in the EU SWAFEA Study (2011) recommendations: "Setting up a knowledge and test capability network within the EU to provide an EU-based fuel evaluation capability".

ITAKA has been built aiming to engage key stakeholders participating in different EU initiatives in the field, to make a first significant step in the establishment of such European network.

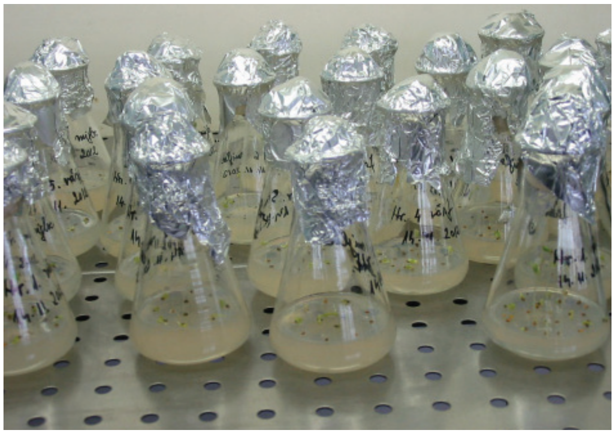
The project is framed in the implementation of the EU policies, implementation of the EIBI of the SET-Plan and specifically aims to be a contribution to the fulfilment of some of the short-term (2015) EU Flight Path objectives and to the implementation of the EIBI of the SET-Plan.

5.4.1.2 Technological/Scientific Impacts

The outcome of this project is significant since a negative result would impede large-scale commercialization whereas a positive impact would support the case for further development.

One of the most important technological steps taken in ITAKA is testing the supply of aviation biofuel through the normal logistic channels. Currently, aviation biofuel is moved through dedicated systems, but when existing infrastructure can be used as a result of non-dedicated system improvements and tests, significant cost reductions can be realised in the down-stream logistics. This will bring the economic viability of biojet fuel a step closer to reality.

One of the potential barriers to large-scale commercialisation in the EU market is the limited supply of EU RED-certified biofuel (see Chapter 3). This project will help overcome that barrier by conducting the first full supply chain certification and by solidifying the knowledge base that must exist in order to produce more certified biofuel: ITAKA will draw recommendations to solve any existing sustainability certification barrier considering a large-scale use framework.



ITAKA shall demonstrate if camelina oil is a viable, large scale sustainable feedstock. Integration of biodiversity and soils' aspects will enlarge the camelina environmental footprint and other biofuels could have. Assessment is the only way to make sure that no major detrimental effects are brought by camelina oil in the production of biojet. In this matter, ITAKA will be of first relevance by producing an up-scaling model based on its results acquired directly from the partners in charge of each step of the process.

5.4.1.3 Policy Impacts

Ultimately, policy, legislation and governance will be the key to balancing ethical principles with technological opportunities and the conflicting array of human needs. However, the development of good effective policy will need to be underpinned by good evidence, and the dimensions of the ITAKA project are such that it represents an opportunity to gather a meaningful datasets from which consequential conclusions may be extracted. For the aviation biofuel industry, sustainable socio-economic development and the rural revitalisation may be the key policy drivers in the future.

The practice-based analysis of potential indirect impacts of biofuel production will serve as basic state-of-the-art findings for the European biofuel sustainability policy in the arena of indirect impacts, concretely in the EU RED.

The main barrier to surpass in certifying larger quantities of sustainable biofuel is the "psychological" barrier associated with subjecting a production facility through the process of certification. The initial "reluctance to certify" stems from a lack of experience with the certification process. The certification of the whole chain will raise scientifically sound information that will help to improve and further develop the regulatory framework.

Complementary to GHG balance and certification focus, LCA will enlighten other key environmental parameters such as water, soils or biodiversity topics which are not quantitatively assessed in present regulatory framework.

5.4.1.4 Economic, Environmental and Social Impacts

For aviation biofuels to gain any appreciable market share, they will need to be produced at industrial scale. However, industrial agriculture based on monocultures bring with them their own share of dilemmas and trade-offs. Producing biofuels that are economically viable, whilst maintaining socio-economic and environmental sustainability, is crucial.

The development of the first of a kind large-scale RSB certified sustainable camelina plantations in Europe will provide the required input, data and results in order to clearly determine the economic, social and environmental sustainability of camelina as a European feedstock for biojet fuel production. Additionally, the project will demonstrate the scalability of the feedstock at a European level using or fine-tuning existing infrastructure and equipment, mainly on the agricultural and processing/crushing areas. ITAKA´s activities examine some important aspects of sustainability that go beyond the EU RED mandate.

The creation of a guide for good camelina agricultural practices will help overcome the greatest barrier today: the farmers' reluctance to explore a crop unknown to them. The diffusion of the crop's name at a European level will serve to that goal if the successful results of the project are duly publicized.

RSB certification, coupled with an analysis of indirect impacts of production of the proposed biokerosene production value chains, will provide an ambitious and thorough assessment of the biofuel across its production chain, taking both direct and indirect sustainability impacts into account. Furthermore, full LCA with additional soil and biodiversity focus are essential to demonstrate sustainability.

In conclusion, ITAKA will help to demonstrate the readiness of the technology to produce aviation biofuels in a socially, and environmentally sustainable manner. With a scale-up model under development by SENASA (Section 5.4.4), these results will be extrapolated to the 2020 scenario to further understand the impact in the medium-long term.

5.4.2 Swedish Biofuels

5.4.2.1 Overview

The EU has demonstrated increased interest in the greening of the aviation industry with substantial financial support for the Swedish Biofuels' technology that converts biomass to jet fuel via alcohols. A pre-commercial industrial scale plant with an annual capacity of up to 10,000 tonnes of aviation fuel and diesel will be constructed.

5.4.2.2 International Consortium

Swedish Biofuels AB will coordinate an international consortium over the next five years with the goal of producing paraffinic biofuels for use in aviation. The project will be performed with the support of the European Commission under the Framework Programme 7.

The consortium consists of organisations with the capability of supplying raw materials, designing, constructing, and operating a pre-commercial industrial scale plant for the production of fully synthetic jet fuel. Consortium members will also offer the possibility of testing the biofuel in aircraft systems. Within the scope of the project, environmental Life Cycle Assessments (LCA) will be carried out. The members of the consortium are Swedish Biofuels (SE, jet fuel production process), Abengoa (ES, municipal solid waste to ethanol), Lufthansa (DE, engine testing and flight), SkyNRG (NL, marketing), E4Tech (CH, life cycle analysis), SCA (SE, raw material supply), Rameski Keskus (EE, equipment), Perstorp (SE, industrial site), LanzaTech (UK, syngas to ethanol) and Vrije Universiteit Brussel (BE, policy studies).

The capacity of the plant will be 10,000 tonnes per year, of which 50% consists of jet fuel, the rest being the byproducts aviation gasoline (AVGAS) and diesel. The jet fuel produced will be compatible, without blending, with in-service and envisaged jet engines for both civilian and military applications. It will consume a variety of sustainable raw materials focusing on wood, municipal solid waste and biogas.

5.4.2.3 Biomass to Jet Fuel Via Alcohols

Less than ten years ago, any suggestion of producing jet fuel from biomass was met with incredulity. At that time Swedish Biofuels considered jet fuel as a possible, but risky, extension to its product development of drop-in diesel and gasoline. This changed in 2006 when the Defence Advanced Research Project Agency (DARPA) contracted Swedish Biofuels to demonstrate its technology for producing a 100 % biological equivalent to JP-8 jet fuel. By 2008, Swedish Biofuels demonstrated this technology, at laboratory scale.

A central feature of the technology is that cellulose, lignocellulose, or some other carbon source, is used as the starting point, the pathway to jet fuel includes the production of alcohols (C2 – C5) and synthesis gas as intermediate products. The key technology achievements are catalysts and processing units capable of producing the complex end product. It was necessary to find ways of producing hundreds of hydrocarbon compounds in order to mimic the properties of military spec jet fuel (JP-8). Systems were developed for synthesizing highly branched paraffins, mono-aromatics and cyclic compounds with particular attention on minimizing the projected cost of full scale production.

Today the alcohol to jet concept is in operation at a pilot plant, which has been in continuous operation for the past two years, producing fully synthetic paraffinic jet fuel. The pilot plant is located at Swedish Biofuels laboratories at the Royal Institute of Technology (KTH) in Stockholm, Sweden. The pilot plant has a capacity of 10 tonnes per year of production of the final products of jet fuel 4.8 tonnes per year, gasoline 3.5 tonnes per year and diesel 1.7 tonnes per year.

5.4.2.4 Certification

The jet fuel produced at the pilot plant, under the code name SB-JP8, is currently being tested by the US AirForce (USAF), as part of a large scale programme to introduce and certify alternative fuels. SB-JP8 has successfully passed all tests to date and the data has been submitted to the relevant ASTM International committee for certification of the fuel for commercial use (see Chapter 2).

5.4.2.5 A Wide Range of Feedstocks

Swedish Biofuels AB patented technology is designed to convert woody biomass to jet fuel and other drop-in transport fuels. The technology is not restricted to wood as the primary source of raw material. As the intermediate products of the process are mixed alcohols and synthesis gas, the Swedish Biofuels technology can be equipped with different front end technologies fully integrating with the overall process. The flexibility provided by having a choice of front end technologies considerably widens the feedstock beyond wood and offers the possibility of implementing the technology globally. Both an alternative front end technology and alternatives to wood as raw material, namely, biogas processing and solid municipal waste, will be demonstrated as part of the project.

5

5.4.2.6 Convince the Market

The overall goal of the project is to demonstrate that the alcohol to jet technology can be scaled up and so provide the necessary confidence for the aviation market to switch to synthetic jet fuel and to invest in plants to meet market demand. Detailed targets include:

- Demonstrating the production of fully synthetic paraffinic jet fuel meeting the Jet A, Jet A-1 and JP-8 specifications;
- Using a variety of raw materials;
- Evaluating the environmental aspects of the process from a life cycle perspective; and
- Evaluating the economic and commercial aspects of the processes and products.
- Reduced carbon dioxide emissions.

The successful completion of the EC project will accelerate the commercial implementation of the technology and the availability of alternative aviation fuels on the market.

5.4.3 BIOREFLY Project

5.4.3.1 Overview

The BIOREFLY project is expected to be a 2000 ton per year industrial scale demonstration biorefinery in lignin-based aviation fuel.

The European Commission supports advanced biofuels research and innovation, particularly in order to improve production processes and to lower costs for biofuel deployment. One of the principal measures is the Seventh Framework Program for Research and Development, maximizing the full use of second generation biomass and biofuels (i.e. originating from the processing of lignocellulosic feedstock such as agro- and forest residues).

5.4.3.2 BIOREFLY Project to Support EU Objective

The BIOREFLY project will receive the support of European Commission, under the EU Call FP7. ENERGY.2013.3.2.1 – Pre-commercial industrial scale demonstration plant on paraffinic biofuels for use in aviation – with the development and construction of an industrial demonstration jet fuel plant from renewable biomass, including key innovative process units for the conversion of lignin – co-product in cellulosic ethanol biorefinery – into a green biofuel.

The project target is the construction of an industrial demonstration plant, owned by Biochemtex S.p.A. and situated in Italy, that will produce 2,000 ton/y of jet fuel by 2017. The feedstock supply is strictly linked with the industrial production of cellulosic bioethanol in the 40,000 ton/y plant of Crescentino, Italy (see Figure 19), through the innovative second generation Beta Renewables-PROESA® technology, invented by Biochemtex.

The key to the success of the second generation technology depends on the assumption that the production of biofuels from renewable sources and environmental concerns can, and must, become a firm and indivisible combination. Therefore, the complete valorization of all lignocellulosic biomass fractions (cellulose, hemicellulose and lignin) is a key point for the definition of a complete value chain sustainable biorefinery, in combination with the selection of the most promising and environmental-friendly technologies of conversion. The project will focus on demonstrating the chemo-catalytic conversion of lignin into jet fuel in an integrated industrial demo scale plant, including innovative, tailor made and cost-effective downstream process. Innovative engineering solution combinations will be tested at industrial scale during operative conditions and the product tested in dedicated engines of the aviation sector.

The present project pursues the objectives of the European Union in terms of reduction of environmental impact and contribution to anti-climate change policies; in fact with the promotion of 2nd generation aviation biofuel at commercial scale, it supports the EU Renewables Energy Directive (2009/28/EC on

Figure 19 – Biochemtex-IBP – 40,000 ton/y second generation bioethanol plant – Crescentino, It

5

the "promotion of the use of energy from renewable sources") and, with a reduction of CO_2 emissions in transport, it sustains the EU requirements and also EU Kyoto targets.

5.4.3.3 Goals of BIOREFLY Project

The main goal of the BIOREFLY project will be the construction of the first paraffinic aviation fuel demo plant at industrial scale completing the lignocelluosic-to-bioethanol production chain through the chemical valorization of secondary streams. Other goals of BIOREFLY project can be summarized in the following points:

- Validate the process technology improvements achieved during the course of demo operations and realize the scale–up to commercial plant.
- Incorporate all components designs into an integrated and techno-economic sustainable process package.
- Confirm the economic viability of process design.
- Ensure that the environmental, safety, health and security requirements are fully incorporated and properly implanted into project's design and execution and can be readily implemented for plant construction in different locations worldwide.
- Test of the jet fuel use in turbines and aviation engines.
- Disseminate the project results to a technical/non-technical audience.

5.4.3.4 Innovative Technology of the BIOREFLY Project

The feedstock of the BIOREFLY process is produced from the conversion of dedicated lignocellulosic energy crops and agriculture residues, not in competition with food sector. The lignin cake derives from the innovative Biochemtex-Beta second generation PROESA® technology, which implements the use of steam for the biomass pretreatment in order to separate lignin from cellulose/hemicellulose, avoiding the addition of chemicals. PROESA® lignin shows very low sulfur and halogens content as compared to other types of lignin (e.g. obtained from pulping processes). This represents an advantage for the BIOREFLY process, being sulfur a 'poison' for catalysts. Finally, the PROESA®-Lignocellulosic biomass Pretreatment technology efficiently separates lignin from the plant sugar polymers, producing a very fine lignin and characterized by a micrometric size distribution, that is of key importance for the subsequent catalytic operations.

With the objective to valorize this biorefinery co-product into biochemical, Biochemtex has developed an innovative chemo-catalytic technology for the conversion of PROESA® lignin into hydrocarbon jet fuel, now operative in the Sharon Center pilot plant from June 2012 (Ohio, US – see Figure 20).

5.4.3.5 Project Implementation

A strong and multidisciplinary consortium, covering regionally the whole of Europe from South to North, consists of key research institute and industrial players in Europe in renewable energy research and production, aviation transport, has been gathered to reach the objective of the BIOREFLY project: i.e. to accelerate the implementation of the second generation biofuel technology at commercial level and use in the aviation sector. The consortium includes small, medium and large enterprises and also research institutes that have an important role in the project for the successful realization of the industrial initiative. Biochemtex Spa is the leading industrial partner of the BIOREFLY Project responsible of the R&D activities, and of the EPC and operation of the 2,000 ton/y jet fuel facility in Italy.

For any information, please contact: Ms Stefania Pescarolo – BIOCHEMTEX SpA – Phone +39 335-1756841 – E.mail: stefania.pescarolo@gruppomg.com – www.biochemtex.com

5.4.4 The Spanish Bioqueroseno Initiative

The Spanish Initiative for the Production and Consumption of Biokerosene for Aviation[30] has its origins after the first International Conference on Alternative Fuels for Aviation that ICAO held in 2009, in which urged States to encourage the development of sustainable alternative fuels for aviation.

bioqueroseno.es

Iniciativa española para la producción y consumo de bioqueroseno para la aviación

After two years of work with stakeholders, the Biokerosene Initiative was formalized in 2011, with the signing of an agreement between the Spanish Ministries of Industry & Energy, Transport (through the Civil Aviation Authority) and Agriculture & Environment. SENASA, a State-owned company linked to the Civil Aviation Authority, coordinates this through the Observatory of Sustainability in Aviation[31] and several stakeholders involved through the value-chain have joined.

Figure 20 – Biochemtex – lignin-to-jet fuel pilot plant – shc, Ohio, US

30. www.Bioqueroseno.es

31. www.obsa.org

The initiative aimed to act as a bridge between the public sector and the private agents to facilitate industrial synergies that would drive the development of aviation biofuels in Spain and Europe.

The Seventh Framework Program of the European Commission requested in 2011 the demonstration of commercial-scale production of alternative fuels for aviation, as well as the study of the implications of large-scale use.

Framed in achieving the objectives of the Spanish Bioqueroseno Initiative, but also as a contribution to the EU objective, SENASA proposed to launch a project involving key actors from different States and regions committed with the deployment of aviation sustainable biofuels.

5.5 Aviation Initiative for Renewable Energy in Germany (aireg)

5.5.1 Overview

aireg – Aviation Initiative for Renewable Energy in Germany e.V. – has made considerable progress in 2013. Whereas 2012 was essential in raising awareness and determining the initiative's goals, 2013 was marked by the initiation of concrete projects to support aireg's strategy for a prompt market introduction of alternative aviation fuels in Germany.

5.5.2 Feedstock development

5.5.2.1 Germany

A consortium of aireg members is assessing and developing several algae-based jet fuel pathways as part of the "AUFWIND" project coordinated by Forschungzentrum Jülich. In order to prepare an industrial-scale algae production, € 5.75 million have been awarded by the German Federal Ministry of Agriculture. The project includes economic and ecologic analysis of the entire value chain and will optimize different photobioreactors to local conditions. After the 3-year project phase with three pilot plants it is intended to build at least one integrated demonstrator of the best-performing pathway.

5.5.2.2 Cameroon

A third feedstock that aireg is pursuing is Jatropha. Together with the German Federal Ministry of Economic Development aireg is investigating the set-up of a lighthouse project in Cameroon that shall incorporate the latest seeds and agricultural best-practices. As an integral part of the project, the local community is to benefit from a strict adherence to sustainability criteria and rural development goals. By demonstrating the economic viability of Jatropha as a feedstock for the production of alternative aviation fuel, the project would serve as a reference for a subsequent expansion of Jatropha cultivation in the region.

5.5.2.3 Russia

The vast amounts of underused land in parts of Southern Russia and the suitability of camelina for the local climate led aireg to support a conference on the crop in Penza/ Russia. Farmers and agricultural conglomerates interested in cultivating camelina founded the Association of Russian Camelina Growers on-site. As a result, several thousand tons of certified camellia oil was already available in 2013. The new Association will foster the cooperation between the agricultural sector and research institutions to provide a significantly larger amount of camelina oil in the years to come.

Figure 21 – Penza Camelina Conference 2013 (from left to right): Mr. Joachim Buse, Deputy Chairman of aireg e.V. and VP Aviation Biofuels at Lufthansa German Airlines, Mr. Vladimir Volkov, Deputy Governor of Penza Region and Mr. Vasiliy Bochkarev, Governor of Penza Region

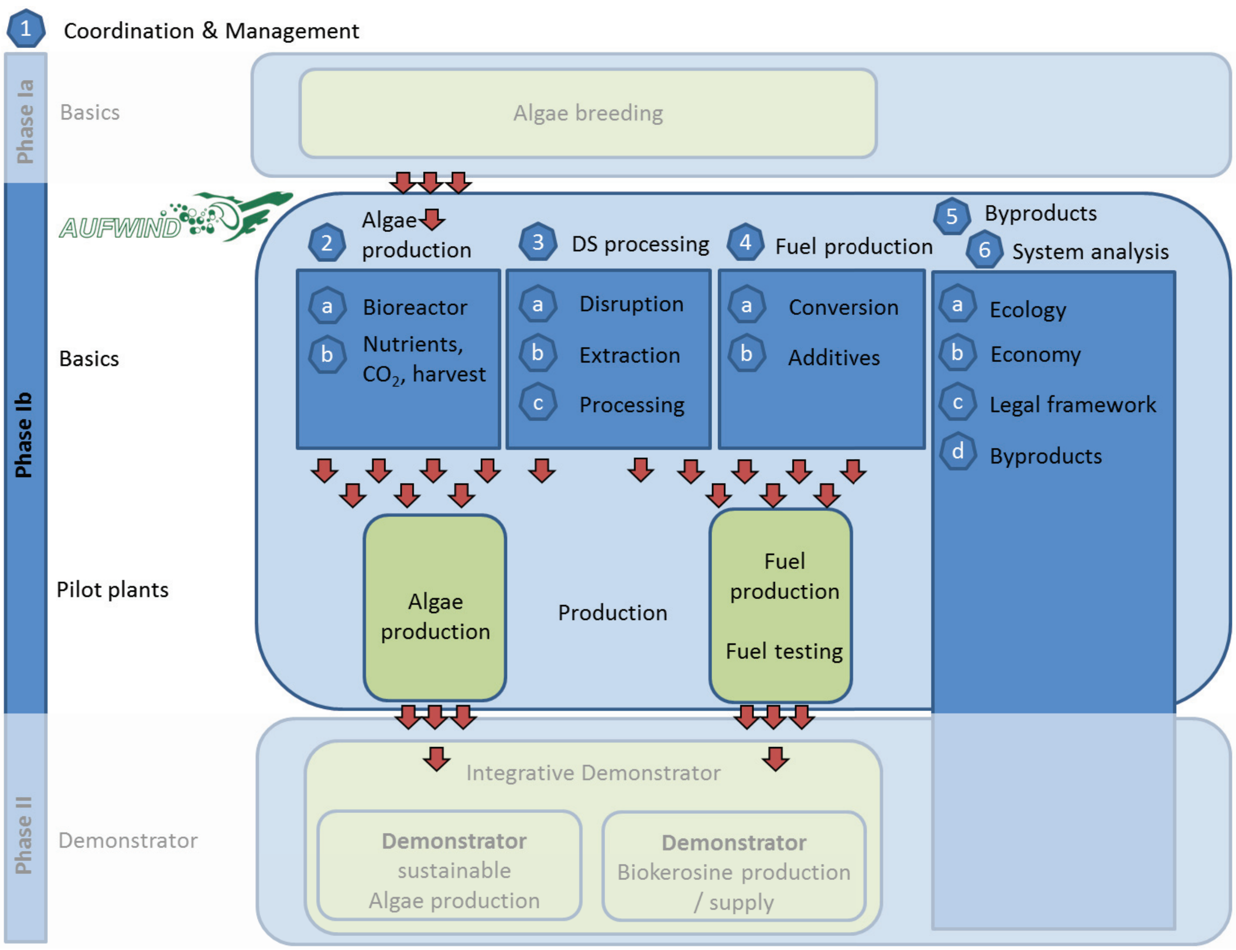


Figure 22 – AUFWIND project structure

5.5.3 Aviation as Part of the German Mobility and Fuels Strategy

The German Federal Government made a tremendous effort in 2012 and 2013 to draft its Mobility and Fuels Strategy. Each mode of transport has been evaluated regarding its fuel efficiency and carbon reduction potential. With a clear commitment to liquid drop-in fuels for aviation the strategy is calling for a National Action Plan for Alternative Aviation Fuels which is to contain a 10,000 t biojet program. The German Federal Ministry of Transport is discussing further implementation with aireg. An important step was a visit by a delegation of the ministry to Washington D.C. to meet with FAA and CAAFI in order to get a firsthand impression of the public support given to alternative jet fuel in the U.S. The existing partnership of CAAFI and aireg is beneficial to this ongoing dialogue, which is supported by a bilateral U.S.-German Government agreement signed during ILA Berlin Air Show 2012.

aireg's market deployment strategy calls for an ambitious public support for alternative aviation fuels from now until at least 2020. The initiative is confident that the ecological and economic benefits can only be realized with initial sizable funding for feedstock development and capacity building for refineries.

5.5.4 Alternative Aviation Fuels Pavilion at Paris Air Show

The most significant gathering of the growing alternative jet fuel sector in 2013 occurred during the Paris Air Show. As in Paris 2011 and in Berlin 2012, the global initiatives of CAAFI, aireg, AISAF and GIFAS put on a remarkable presence with their Alternative Aviation Fuels Pavilion (AAFP) run and organized by Kallman Worldwide. With numerous international exhibitors and an attractive presentation program throughout the week, the AAFP drew significant crowds. Given its previous success, AAFP will once more be the center of gravity for all value chain partners during Berlin Air Show 2014.

5.5.5 Policy Statements

The European discussion about amending the road transport's biofuel mandate has impacts on the aviation sector, as well. It is contemplated to introduce a penalty for indirect land-use change (ILUC) for various feedstocks. This is meant to account for an assumed diversion of food production to land deserving protection. The penalty would e.g. be identical for all plant oils regardless of their origin, thus negatively impacting their carbon life-cycle analysis. In a policy statement aireg is urging German and European administrations to apply a sound differentiation as regards feedstock origin and to allow for a project-specific ILUC assessment. In the long-term, the entire agricultural production, not just the production of feedstocks for biofuels, should need to be certified with respect to land history, thus accounting for direct rather than indirect land-use changes.

aireg welcomes ICAO's decision to introduce a global market-based mechanism to achieve carbon-neutral growth from 2020. However, a net reduction of carbon emissions is only possible through the use of alternative aviation fuels. It is therefore essential to act now and pave the way for truly climate-friendly aviation.

5.6 Flightpath to Aviation Biofuels in Brazil: Action Plan

The Sustainable Aviation Biofuels for Brazil project, a collaborative effort of FAPESP, Boeing and Embraer, reached a significant milestone, the publication of "Flightpath to Aviation Biofuels in Brazil: Action Plan.

The project main objectives were:

- To develop a roadmap to identify the gaps and barriers related to the production, transportation and use of biofuels for aviation;
- To create the basis for a research and commercialization agenda to overcome the identified barriers to the development of a sustainable aviation biofuels supply chain with significant greenhouse gasES (GHG) mitigation potential;
- To establish the foundation to launch a new and innovative industry in Brazil to produce sustainable biofuels for aviation.

The study, conducted by UNICAMP (the State University of Campinas), encompassed eight workshops in Brazil with the collaboration of more than 30 stakeholders with strong focus on feedstock, refining technologies and logistics. Sustainability as a critical issue was considered throughout the supply chain. Polices to implement this new industry was one of the outcomes. In addition, there were three regional outreach workshops, conducted by EPFL and 4CDM, which helped broaden the range of perspectives on challenges and opportunities.

5.6.1 Feedstock

There is no single, perfect feedstock to produce a jet biofuel in Brazil but rather a wide range of feedstocks. Eucalyptus and pine grown in lands with high slopes, sugarcane in tropical and subtropical zones, while different crops are suitable to different latitudes such as dende in south Para state, while starch and oil crops can be grown in most of Brazil. There is also an abundant supply of residues such as lignocelluloses, tallow, used cooking oil, municipal solid wastes, and industrial waste residues.

Brazil is the world's largest producer of sugarcane, second of soybeans, and has the lowest cost of production of eucalyptus. Several other crops will require some additional efforts in R&D to become commercial crops with high yields (jatropha, camelina, sweet sorghum), reduced costs (jatropha, camelina, sunflower, peanuts, castor beans, palm, and other oil-bearing crops), as well as to solve harvesting problems (jatropha, grasses). For crop residues (straw, sugarcane bagasse, and forest by-products) collection and transportation costs, and questions of removal rates to preserve soils are the main gaps and barriers that must be overcome. Industrial waste residues are widely available in the Brazilian steel industry. Tallow, another by-product, is already widely used to produce biodiesel in Brazil, but the other residues require considerable efforts to solve collection and/or separation problems.

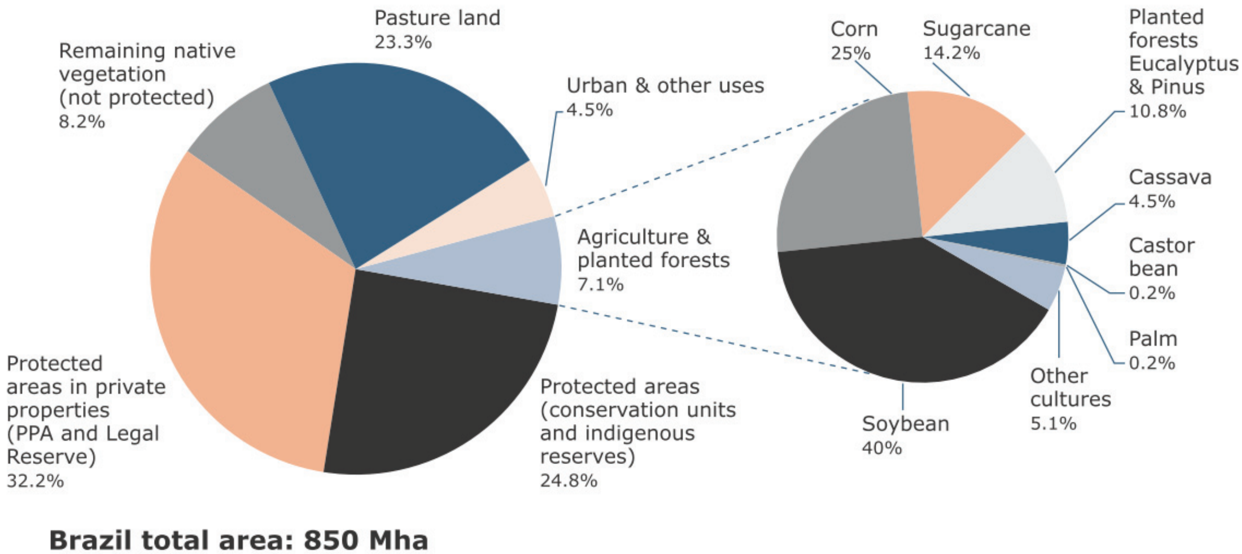


Figure 23 – Land use and planted area with some biofuel feedstock in Brazil and potential for expansion.

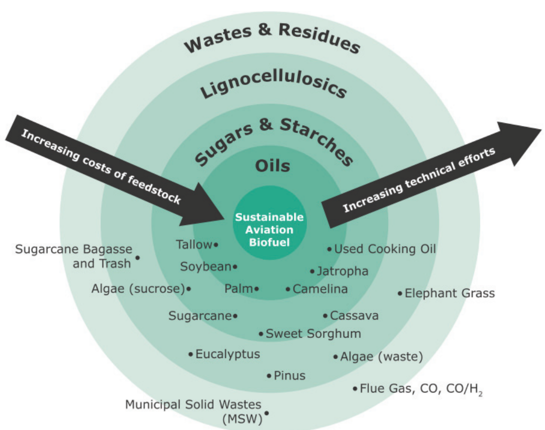


Figure 24 – Feedstocks and their relative position according to costs and technical efforts to be converted to aviation biofuel. For illustrative purposes only. Feedstock prices and technical efforts will vary significantly.[32]

Considering the 2020 horizon, the most productive sources of bioenergy from the standpoints of crop yield and energy balance are sugarcane and forestry. These would be the option of choice for aviation biofuels if this was the final criteria. However, the optimization of the country's ample land resource may contemplate other crops as well.

5.6.2 Conversion and Refining Process

Current technologies allow conversion of agricultural feedstocks to "drop-in" jet fuel. Figure 25 below depicts the identified pathways for the production of sustainable aviation biofuels in Brazil. All these technologies have potential to be considered for the production of jet biofuel.

In Brazil, fermentation of carbohydrates (sugars) to hydrocarbons or to lipids is reaching commercial stage, with first-of-a-kind installations getting into operation.

Promising short-term possibilities include the use of sugarcane sucrose and ethanol, since they can benefit from low sugarcane production costs and good sustainability indicators in Brazil. However, in the medium to long term, it appears that fiber cellulosic feedstocks such as wood-derived products and sugarcane trash and bagasse will have better competitive possibilities due to their high sustainability values, and less competitive existing markets. Several other feedstocks may have medium and longer term potential for cost effective production.

5.6.3 Sustainability

The sustainability assessment for the production of feedstocks in Brazil was carried out according to the principles and criteria of the currently available and most

32. This Figure does not represent the views of all stakeholders in the Project.

well-known international sustainability standards for biofuels production, namely Bonsucro and Roundtable on Sustainable Biomaterials (RSB – See Chapter 3). Although there are important differences among the feedstocks, some general common conclusions can be made regarding biofuels production and the gaps to comply with sustainability requirements.

In the social sphere, the main positive impacts are the high potential for job creation, income generation and regional development. Regarding the gaps for compliance with sustainability requirements, the following aspects were common: great number of laws and rules, sometimes stricter than sustainability standards; different interpretations and lack of knowledge on how to apply laws; uneven enforcement and certain labor laws not adapted to the rural context. There is also a need for qualification and training of workers.

Regarding environmental aspects, the main potential positive impact generated by compliance with requirements is GHG emission reductions compared to fossil fuels, especially in the sucrose and cellulose groups, although there are still some difficulties with calculations and data.

Brazilian laws are quite strict to protect natural resources, water and biodiversity. The Brazilian Forest Code is among the most restrictive legislation on land use. Labor laws are equally severe. The real issue is how to improve the sustainability of agriculture in general, which requires economic resources to promote the farmer's necessary cultural change.

5.6.4 Logistics

Logistics improvements will be needed for most crops in the transport infrastructure. Most feedstocks are bulky material or have low unit value. The improvement of feedstock and jet biofuel logistics is a significant need for the economic competitiveness of the various pathways for the production of jet biofuels. It is necessary to develop logistic studies for investment on

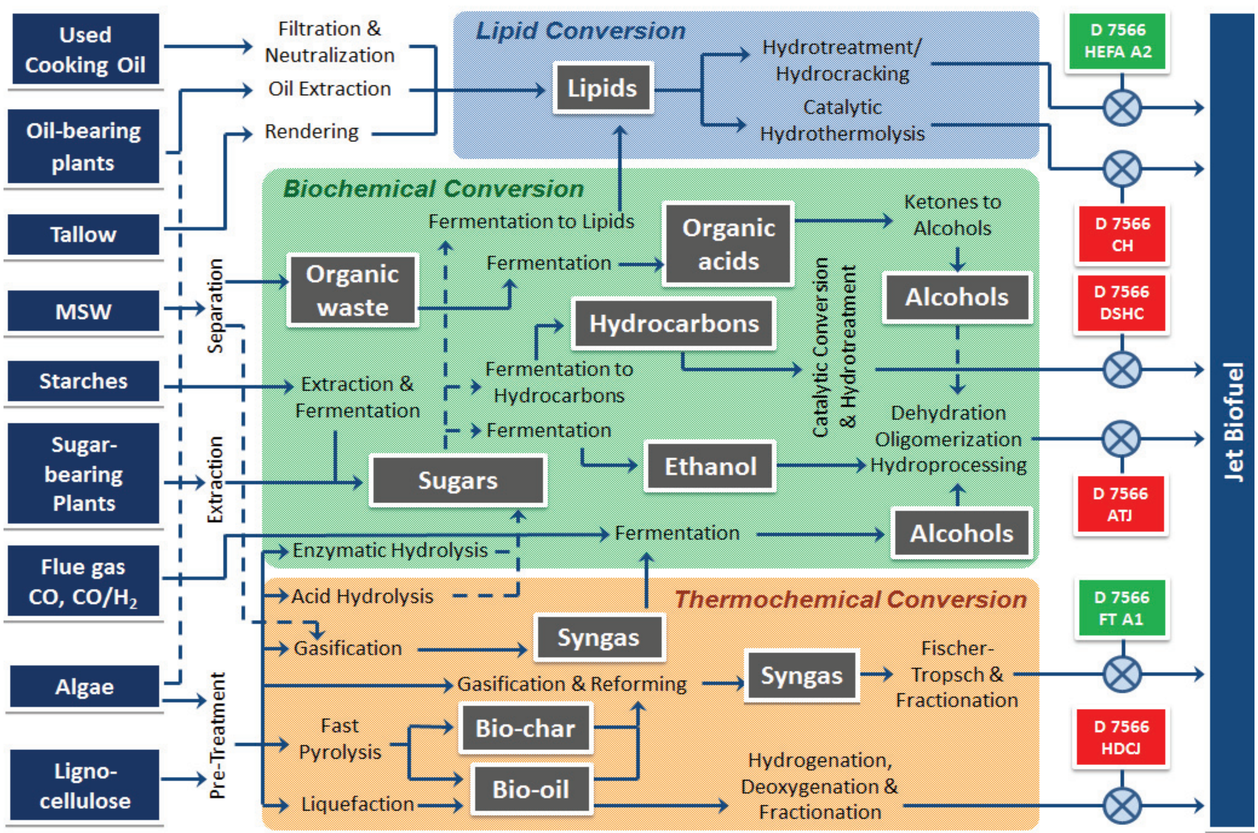


Figure 25 – Identified pathways for the production of sustainable jet biofuel in Brazil[33]

33. [Note: HEFA – Hydroprocessed Esters and Fatty Acids; CH – Catalytic Hydrothermolysis; DSHC – Direct fermentation of Sugars to Hydrocarbons; ATJ – Alcohol to Jet; FT – Fischer-Tropsh hydroprocessed synthesized paraffinic kerosene; HDCJ – Hydrotreated Depolymerized Cellulosic to Jet].

railways and waterways taking into account feedstocks for biofuels in general and jet fuel specifically and make sure that the cost advantage of Brazilian agriculture products in international markets is reflected in aviation biofuels production similarly to other biofuels.

5.6.5 Conclusion

The main policies and actions required are as follows:

- Establish the "drop-in" sites as far as possible downstream in the distribution chain without compromising fuel quality and technical certification requirements of aviation;
- Establish legal mechanisms to ensure that incentives for aviation biofuels are only available where demonstrated to fully implement national laws and regulations, especially environmental and social safeguards, natural forest and other habitat protections, land use zoning and worker protections;
- Observe closely and anticipate regulatory actions by ICAO in such a way to take advantage of international regulations to promote a jet biofuel industry in Brazil;
- Establish a governmental long-term program for integrated use of biofuels in all transportation modes in the country, to neutralize the cost difference of producing a "drop-in" fuel versus a product for biofuel-adapted engines as is the case for road transportation.

6. Notable Developments

6.1 Chapter Summary

While many notable developments have occurred in alternative aviation fuels over the past 12 months, a few examples are highlighted in this chapter.

- In mid-2012 the Midwest Aviation Sustainable Biofuels Initiative (MASBI) was established. This group has effectively gathered more than 40 public and private organizations representing the entire biofuels value chain with a specific focus on mid-western United States.
- As part of an agreement with AltAir Fuels, United Airlines will purchase five million gallons of biofuel per year over a three-year period, totaling 15 million gallons of sustainable biofuel.
- After multiple demonstration flights and several commercial flights (including the longest transatlantic flight on sustainable biofuel), KLM introduced a series of weekly flights for a period of 6 months from New York to Amsterdam.
- Activity in the Nordic regions is represented by The Nordic Initiative for Sustainable Aviation, NISA – which is established by Nordic stakeholders within the aviation sector and are now joining forces to facilitate the development of a sustainable aviation fuel.

IATA gratefully acknowledges Jimmy Samartzis (United Airlines/MASBI), Robert Arendal (NISA), Fokko Kroesen (KLM), Maarten Van Dijk (SkyNRG), Darrin Morgan (Boeing) and Frederic Eychenne (Airbus) for their contributions to this chapter.

6.2 Midwest Aviation Sustainable Biofuels Initiative (MASBI)

6.2.1 Summary

In June 2012, United Airlines, Boeing, Honeywell's UOP, the Chicago Department of Aviation and the Clean Energy Trust, launched the Midwest Aviation Sustainable Biofuels Initiative (MASBI).

The initiative involved more than 40 public and private organizations representing the entire biofuels value chain, including an Advisory Council chaired by Argonne National Laboratory. MASBI strategy and program management support was provided by Oliver Wyman, a global leader in management consulting with recognized expertise in energy and aviation. According to the final report, issued by the group in June 2013, the commercial aviation industry has a clear path toward cleaner, more economical and more secure energy alternatives. Participants and Advisors in MASBI included organizations such as the Departments of Navy and Agriculture, the NRDC, the Farm Bureau, Airlines for America, CAAFI, GE Aviation, Iowa State and Purdue Universities, Virent and Monsanto.

The group concluded that the Midwestern United States is a natural fit to advance aviation biofuels given that it is home to one of the world's largest airlines. The region also offers feedstock availability and viability, a concentration of clean technology leaders, a vibrant funding community, airports supporting sustainability, and policymakers focused on advanced biofuels. MASBI leveraged the expertise of stakeholders from across the aviation biofuels value chain to develop an action plan to accelerate the development of the advanced biofuels industry. That plan highlights several opportunities and recommendations to support and advance commercial-scale development of aviation biofuels.

MASBI produced the report following a year-long analysis of the benefits that could be delivered from a robust sustainable aviation biofuels industry in the Midwest. Noting the progress made in developing biofuels, including its use on more than 1,500 commercial aviation flights globally, the coalition agreed that more must be done to achieve the sustainable production of commercial-scale and cost-competitive advanced biofuels from sources such as non-food crops and waste products. MASBI issued its report in Chicago at a summit of aviation and energy experts, biofuel developers, environmental organizations, government officials and research institutions.

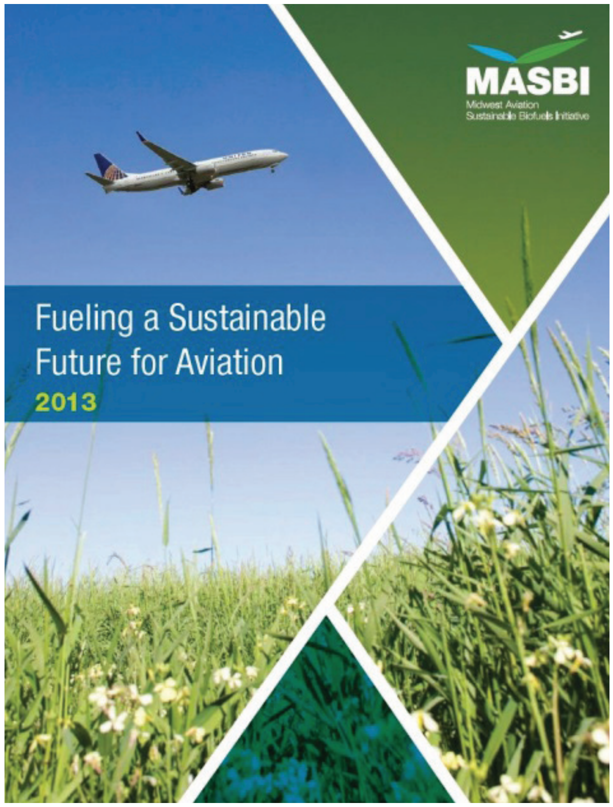
The aviation industry is interested in the development of alternatives to petroleum-based jet fuels to address its largest operating cost and most significant impact on the environment. The benefits of building this industry extend beyond aviation. Developing a commercial market for aviation biofuels has the potential to create jobs, generate economic growth, and further contribute to innovation.

The report recommendations include the following:

1. Improve feedstock production through agricultural innovation
2. Tailor agriculture products such as oil-seed crops for jet-fuel production
3. Investigate the impacts of uncertainty on production
4. Advance technologies to convert lignocellulosic biomass

5. Identify means to expedite approvals by the ASTM International and the Environmental Protection Agency
6. Allow producers to optimize product portfolios
7. Pursue deal structures that balance risk and reward for early adopters of technology
8. Demonstrate industry demand with aviation jet fuel purchase guidelines
9. Create pool of capital to invest in biofuels
10. Create longer-term policies that enable investment and production
11. Level the policy playing field for advanced biofuels with the conventional petroleum industry
12. Fully fund the Defense Production Act Title III for the production of biofuels
13. Build regional demonstration facilities supported by municipal and state policies
14. Incorporate sustainability standards and advance certification

In addition to endorsing the report's recommendations, the MASBI Steering Committee leadership and stakeholders announced concrete commitments to help secure a robust future for biofuels. Since making these commitments, the members have already made significant progress toward achieving them.



6.2.2 Commitments by the MASBI Steering Committee

- Together with the Chicago Department of Aviation, United signed a Memorandum of Understanding to initiate a cooperative effort to identify opportunities to develop advanced alternative fuels for aviation use with a particular focus on converting waste streams in the Chicago area into lower-carbon aviation fuel.
- Along with Honeywell's UOP and Boeing, United Airlines provided funding for Purdue University to research ways to convert corn stover – leaves and stalks left in fields after the corn harvest – into jet fuel. The companies' funding supports existing research and development funding from the Indiana Corn Marketing Council and Iowa Corn Growers Association.
- On September 17, United issued a Request for Proposal for the development and purchase of cost-competitive, sustainable, renewable jet fuel and renewable diesel to supply one of United's hub locations. Using guidelines and technical requirements presented by MASBI Advisory Council member Commercial Aviation Alternative Fuels Initiative (CAAFI), the intent is to emphasize market demand, spur innovative approaches to partnership across the value chain, and obtain delivery of renewable fuel to be used in daily operations.
- In partnership with Boeing and Honeywell's UOP, United is funding the development of a $50,000 prize at the Clean Energy Trust's 2014 Clean Energy Challenge. The prize will be directed towards advanced biofuels projects in the Midwest. The Clean Energy Challenge has been a catalyst in jump-starting innovation within the Midwest by allowing clean energy entrepreneurs at varying stages of development to compete for funding and to receive other resources for growth, improving their chances of success.
- Steering Committee members supported the awarded group of Universities in their bid for the Federal Aviation Administration's (FAA) new Air Transportation Center of Excellence (COE) for alternate jet fuels and the environment. Steering Committee members Boeing, United, Honeywell's UOP and the Clean Energy Trust were all organizational partners for the Center of Excellence and are committed to supporting this ongoing research, which is critical for the future sustainable growth of the aviation industry.

The MASBI Final Report can be found at www.masbi.org. For additional information regarding MASBI, please contact Meg Whitty at Margaret.whitty@united.com.

6.2.3 United Airlines and AltAir Fuels Purchase Agreement

In 2013, United Airlines became the first U.S. airline to sign a definitive purchase agreement for sustainable, advanced aviation biofuels, representing a major milestone for the aviation biofuels industry. This agreement is significant not only in that it is a first-of-a-kind agreement of this scale, but also because the fuel is being purchased at cost-competitive prices with conventional jet and diesel fuels. As part of the agreement with AltAir Fuels, United will purchase five million gallons of biofuel per year over a three-year time period, totaling 15 million gallons of sustainable biofuel for the airline. The AltAir refinery is located outside of Los Angeles and will convert non-edible natural oils and agricultural wastes into low-carbon, advanced biofuels and chemicals. United will use the biofuel on flights operating out of its Los Angeles hub (LAX). The first delivery of the fuel is scheduled for 2014. AltAir has partnered with an existing oil refiner for the operation of its first commercial facility and use of the refiner's existing refinery near Los Angeles, Calif. The partnership involves taking idled refining equipment and retooling it to increase the nation's energy supply – positively impacting the southern California economy and providing the opportunity to sustainably power LAX flights.

Through process technology developed by Honeywell's UOP, AltAir is retrofitting an existing refinery to produce renewable biofuel. AltAir has worked extensively with Honeywell's UOP to demonstrate the commercial viability of the Honeywell Green Jet

process. Utilizing this technology, licensed from UOP, the AltAir facility will be the first refinery internationally to be capable of in-line production of both renewable jet and diesel fuels. The facility will convert non-edible natural oils and agricultural wastes into approximately 30 million gallons of low-carbon, advanced biofuels and chemicals per year.

These advanced biofuels are drop-in replacements for petroleum-based fuel, requiring no modification to factory-standard engines or aircraft, with which they are fully compatible. This fuel provides the same performance as conventional, petroleum-based jet fuel. AltAir Fuels' renewable jet fuel is expected to achieve at least a 50 percent reduction in greenhouse gas emissions on a lifecycle basis.

United will support AltAir Fuels' efforts to incorporate internationally recognized sustainability standards, such as those being developed by the Roundtable on Sustainable Biomaterials (RSB). RSB is an international, multi-stakeholder initiative that brings together farmers, companies, non-governmental organizations, experts, governments and inter-governmental agencies concerned with ensuring the sustainability of biomass production and processing.

For additional information regarding AltAir, please contact Greg Kozak at Gregory.kozak@united.com.

6.3 Innovative Developments at KLM

In 2013 KLM took new steps to stimulate a continuous supply of sustainable biofuels for civil aviation. After demonstration flights followed by several commercial flights including the longest transatlantic flight on sustainable biofuel, KLM introduced a series of weekly flights for a period of 6 months from New York to Amsterdam. By doing so the company made further progress in developing the biofuel value chain and in promoting the importance of a breakthrough for scalable, affordable and sustainable biofuels.

KLM has entered into new and innovative partnerships both with corporate clients as well as suppliers, airports and logistic partners to encourage multi-hub operations and share expertise next to developing new markets for sustainable biofuels.

6.3.1 New Partnerships

KLM believes that cooperation is key for the future of sustainable biofuel in the aviation industry, in order to make a real impact on lowering the environmental footprint.

In June 2012, KLM launched the world's first Corporate bioFuel programme for contracted corporate accounts. This allows the staff of the contracted companies to fly a part of their company travel or their travel on specific routes on sustainable biofuel. The programme aims to stimulate the further development and production of biofuels and as such reduces the aviation industry's carbon footprint. In one year, the number of programme partners has more than doubled to fifteen. KLM's BioFuel Programme now includes the City of Amsterdam, Loyens & Loeff, PGGM, FMO, Delta Air Lines, Siemens, TomTom and CBRE Global Investors. They followed initial customers including Ahold, Accenture, DSM, Heineken, Nike, Philips and Schiphol Group who have been supporting KLM's BioFuel programme from the very beginning.

In 2013 KLM, Schiphol Group, Delta Air Lines, and the Port Authority of New York initiated a joint project and expanded cooperation resulting in the series of flights from New York with sustainable biofuel.

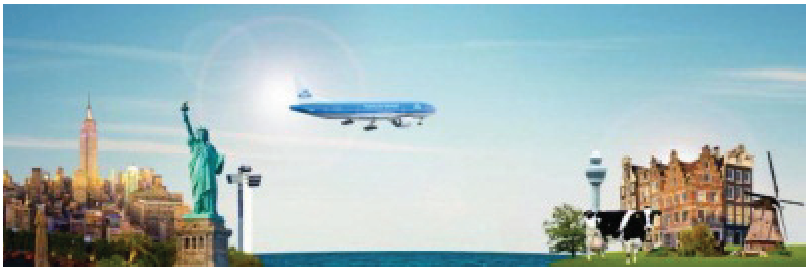
6.3.2 The JFK Series

This first intercontinental series of biofuel flights from New York to Amsterdam again proves KLM's pioneering role in the development of sustainable biofuel. 8 March 2013 marked the start of the 26-week series of flights from JFK. This also provided the Port Authorities of JFK to gain expertise on the logistics and regulations regarding the use of biofuel, thus creating a dual biofuel port next to Schiphol.

The sustainable jet fuel used for the weekly flights on B777-200 aircraft was 100% US-based fuel made from used cooking oil (UCO) and camelina oil sourced and supplied by SkyNRG. SkyNRG is the first fully renewable jet fuel supply chain certified by RSB and is partly founded by KLM. RSB has set the world's highest standards that respect people and the environment when producing biofuel.

KLM and SkyNRG have introduced a variety of measures to guarantee and monitor the supply chain's sustainability, SkyNRG has installed an independent Sustainability Board consisting of leading NGOs and scientists who provide advice about feedstock and technology decisions.

The lifecycle greenhouse gas emission reduction from pure bio-derived aviation fuel varies depending on extraction and processing arrangements, as well as on the type of feedstock used. In general sustainable jet fuels made from UCO can provide a reduction in overall CO_2 lifecycle emissions up to 80% compared to fossil fuels; for sustainable jet fuels made from camelina, this is currently 70%. These figures include the emissions from the production of the fuel, such as transportation and refining.



Dutch partners for
more sustainable aviation
and nature conservation

KLM | WWF

6.3.3 From Flight Series to Continuous Supply

In recent years, KLM has shown that flying on biofuels can be done in a safely and sustainably. The next step is to create a market for bio-jet fuel that complies with strict environmental criteria while meeting economic and social sustainability criteria. This should lead to a significant increase of available bio-jet fuel in the years to come. For this reason, KLM has signed a purchase agreement with the ITAKA consortium. The collaborative programme is expected to demonstrate the readiness of the large scale production of sustainable Synthetic Paraffinic Kerosene (SPK) in the EU.

Cooperation between all partners to invest and innovate in different aspects of the supply chain will be further elaborated. KLM believes that the aviation-industry can establish a dominant position in the fast-growing business of production, supply and deployment of sustainable bio-jet fuels. That is why KLM has engaged with the ITAKA project and platforms such as Climate KIC, BioBased Industries and BE-BASIC. Most recently, KLM agreed jointly with the Dutch government, Neste and logistics partners on the next step to create a continuous supply of sustainable biofuels and developing the first bioport in the Netherlands.

Close cooperation between the stakeholders in an open dialogue and with transparency to NGOs and scientific organisations is a precondition in achieving our goal. In 2011 KLM and WWF-NL signed a partnership to develop a more sustainable aviation industry and encourage the market for sustainable biofuels in order to reduce CO_2 emissions. At present, KLM and WWF-NL base the sustainability of the biofuels on the strict criteria set by the Roundtable on Sustainable Biomaterials (RSB) and the advice of the independent Sustainability Board to SkyNRG.

6.4 Alternative Fuel Developments in the Nordic Countries

6.4.1 Overview

Climate Change, Global Warming, Pollution, Sustainability, Food Shortage, Growing World Population and you-name-it-Green; subjects that we read about almost daily in the media and issues that concerns us all. Most human activities in our society and daily life cause GHG emissions and pollution – and aviation is no exception (2% to 3% of the total, global manmade CO_2 emissions). Consequently, we hear voices stating “stop flying, it pollutes” and “the world is in financial crisis, we can’t afford investing in a transition to alternative energy, away from a society based on fossil fuels”.

To quote James Hansen of NASA ”Global warming is not a problem for the future; it’s a crisis for this moment! – It’s a task for our generation!” The good news is that aviation is being extremely proactive in efforts to reduce such CO_2 emissions by introducing new aircraft and engine technology as well as new operational procedures – and alternative fuels.

The latest IPCC report underlined and emphasized that we are moving too slowly and we shall have difficulties to keep even the maximum 2 degrees Celsius ceiling that the UN and many others have set as the “acceptable” increase in average global temperature before we reach a ”point of no return”. This is further recognition and confirmation of the seriousness of this issue.

6

6.4.2 Nordic Initiative for Sustainable Aviation (NISA)

The Nordic Initiative for Sustainable Aviation, NISA – is established by Nordic stakeholders within the aviation sector and that are now joining forces to facilitate the development of a sustainable aviation fuel. Among all the actors it is understood that aviation must become more sustainable and alternative fuel is one of the means to achieve the goals.

The actors behind the initiative are the Nordic airports, airlines and their associations as well as aviation authorities. The initiative is supported by IATA as well as aircraft manufacturers Boeing and Airbus.

The parties have come together to form a network organization to facilitate this sustainability transition of the aviation industry and voice the concern that aviation gets its share of the limited biofuel resources. Sustainable crops, raw materials and surplus products from forests, agriculture, industry and households are increasingly in demand.

Technology to produce jet fuel is in its infancy but aviation is prepared to switch to the use of alternative fuels. The internationally approved specifications mean that products are fully in line with the current jet fuel used today and certification also ensure that the "drop-in" alternative fuels can be used in existing engines on all jet aircraft in a mix up to 50%.

In the battle to secure their share of the limited resources, the industry is concerned that the energy sector and the road transport are prioritized. Furthermore, in contrast to the other types of transportation, aviation does presently only have one choice to replace fossil based liquid fuels, namely sustainable, renewable bio based alternative fuels – also called biofuels.

The Nordic initiators will focus on bringing together stakeholders throughout the supply chain to find the best and most energy efficient solutions as well as at the same time put pressure on policy makers to ensure that aviation secure its share of the alternative fuels. The task is quite extensive and involves stakeholders from agriculture, technology suppliers, investors, regulators, producers and oil suppliers.

NISA believes aviation is not prioritized in the energy policy discussions despite being an important part of the regional infrastructure. Further, research and development of alternative fuels for aviation should be encouraged in the form of Public Private Partnerships.

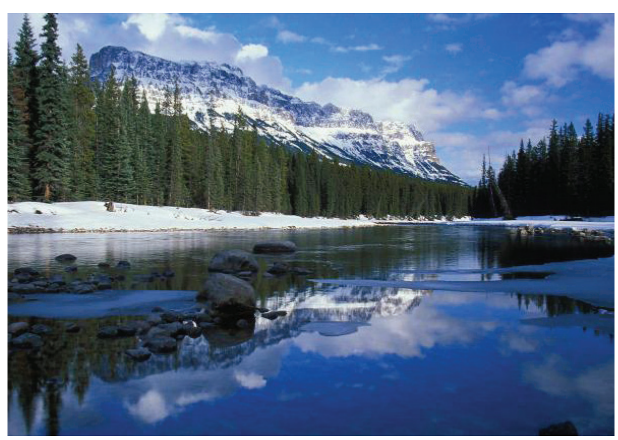
Therefore, the Nordic initiative is in dialogue with parallel activities in the EU and the rest of the world. The support by Boeing and Airbus are of paramount importance since both aircraft manufacturers have participated in the establishment of similar network organizations in other parts of the world.

6.4.3 Key Stakeholders of NISA

Airlines	SAS, Finnair, Norwegian, Icelandair, Air Greenland, Malmo Aviation, Atlantic Airways
Organizations	Danish Aviation, SBN, Svenskt Flyg, Svenska FlygBranschen, NHO, IATA
Authorities	DK/Trafikstyrelsen, SV/Transportstyrelsen, FI/ Ministry of Transport.
Airports	DK/Copenhagen Airports, SV/Swedavia, NO/Avinor, FI/Finavia, IS/Isavia
Manufacturers	Boeing, Airbus

6.4.4 Feedstock Alternatives

The Nordic countries have various alternatives for feedstock for alternative fuels; one such product is the Nordic forests. By implementing a sustainable forestry plan, the huge resources available can be managed in a way that can procure feedstock for alternative fuels and at the same time provide natural forests and plants that absorb CO_2 to reach a neutral balance of the emissions that the production, harvesting, handling and use of biofuels inevitably bring about. Forestry products are available in abundance, are not in general considered suitable for food and the process can be managed in a way that fully respect biodiversity and the environment.



While the stakeholders are presently reviewing and analyzing technology options, feedstock sources and availability, NISA believes test facilities will be available within 3-5 years and full-scale production within a decade.

To achieve this, major stakeholders and government commitments have to be agreed upon and investors assured of the sound business of sustainable, alternative fuels.

Last but not least, the aviation industry is a responsible and forward looking business; reduction of aviation's CO_2 emissions and GHG is together with safety its foremost concern. The use of alternative fuels must reduce these emissions, must respect biodiversity and the environment, not compete with human food requirements, minimize the use of fresh water while wisely use present and future technologies for the limited resources we have available. And mankind's wisdom shall make this transition possible within acceptable parameters – all for a better world.

6.5 SkyNRG

After enabling many of the first commercial bio jet fuel initiatives in 2011 and 2012, the launch of innovative co-funding mechanisms (e.g. SkyNRG's Corporate Program) in 2012 and scaling up to structural green routes in 2013 (e.g. KLM's green route to JFK) SkyNRG is looking to the future. To take this market to the next level the industry recognizes the need for dedicated bio jet fuel production capacity. SkyNRG's efforts will be directed towards achieving this. The SkyNRG Bioport proposition and the Corporate Program will play an important role in this.

In the last year SkyNRG has started to roll out its Corporate Program beyond KLM, with selected airlines around the world. SkyNRG expects the program to be fully active during the first half of 2014.

During 2013 SkyNRG invested in its Bioport proposition, which essentially creates a demand centre at the end of the supply chain (airport/airline combination) and from there helps to structure a regional bio jet fuel supply chain. A regional effort, in which the airline plays an instrumental role in enabling the supply chain, has multiple benefits including significant GHG reductions. For example, it reduces price volatility, helps improve regional energy security, brings social economic development to (rural) areas, stimulates innovation and research & development, and creates a basis for new industries to grow or existing industries to diversify. Furthermore it engages a wide range of (local) stakeholders as well; government, farmers, industry, investors, knowledge institutes, NGOs etc.

A first tangible result of this strategy was announced in April 2013, when SkyNRG launched its first Bioport with Virgin Australia and Brisbane Airport Corporation[34]. The partnership expects to have a commercial scale, regional bio jet fuel supply chain up and running before 2020.

6.6 Airbus's renewable fuel activities

Airbus's sustainable aviation fuel strategy is focused around three central principles; to support the qualification and certification of new aviation fuels, to support the large scale use of sustainable aviation fuels and to target the sustainability of the solutions.

6.6.1 International partnerships and research projects

Airbus's strategy is managed around the world through partnerships and research projects. 2013 saw the launch of an initiative with BioFuelNet Canada and Air Canada to assess the solutions in Canada for the production of sustainable aviation fuels for the Canadian aviation market. This partnership followed the Perfect Flight completed by Airbus and Air Canada in 2012, bringing together all best practices including operational, maintenance, air traffic management and the use of sustainable fuels to achieve an over 40% reduction in CO_2 emissions on a commercial flight from Toronto to Mexico City. The collaboration between Airbus and Air Canada was rewarded with the 2013 Eco-Partnership Award given by Air Transport World.

34. [http://www.virginaustralia.com/au/en/about-us/media/2013/VA_BRIS_SKYNRG_BIOPORT/

Airbus also came together in 2013 with Air France, Total and CFM to perform a demonstration flight at Le Bourget Air Show using an Airbus A321 with fuel efficient sharklets and BioJet A-1 biofuel from Total/Amyris produced through an innovative conversion of sugar.

Further collaborations launched in 2013 included a cooperation agreement between Airbus and Rostec group in Russia to launch a large-scale analysis of Russian feedstock and to evaluate how to speed up the development and commercialization of sustainable fuels in the region.

Airbus believes a key element of the development of sustainable fuels for aviation is political support and frameworks to ensure optimization, financial investment and sustainability. In this spirit, Airbus works closely with the EU commission through ITAKA (Initiative Towards sustAinable kerosene for Aviation). This collaborative project is framed in the implementation of the European Union policies specifically and aims to contribute to the short-term (2015) EU Flight Path objectives. The ITAKA project is expected to support the development of aviation biofuels in an economically, socially and environmentally sustainable manner, improving the readiness of existing technology and infrastructures (see Section 5.4.1 for further details on ITAKA).

In addition to ITAKA, Airbus participates in SAFUG (Sustainable Aviation Fuel Users' Group) in the USA, SA (Sustainable Aviation) in the UK, and NISA (Nordic Initiative for Sustainable Aviation) in Northern Europe.

Initiatives launched over recent years are now beginning to come to fruition. In 2012, Airbus launched its collaboration with Tsinghua University in China to complete a sustainability analysis of Chinese feedstocks and to evaluate how best to support the development of a Chinese value chain to speed up the commercialization of sustainable aviation fuels. This value chain aims to produce and promote the use of sustainable aviation fuel in China, the world's fastest growing aviation market. The first report from this collaboration has been successfully delivered allowing Airbus and Tsinghua to move forward in the next step of this collaboration.

Airbus believes it is necessary to have both a long-term vision and short-term strategic actions to ensure the development of sustainable fuels for aviation. The achievements in 2013 will allow Airbus to prepare for 2014 and beyond to face the challenge of ensuring large scale use of sustainable fuels in the future.

Figure 26 – Air Canada's 'Perfect Flight' fueling operations.

Figure 27 – A KLM Boeing 777-200 is fueled at John F. Kennedy International Airport in New York. Photo source: SkyNRG

6

6.7 Boeing's renewable fuel activities

6.7.1 Asia Pacific

Boeing sponsored and provided significant content to an Association of South East Asian Nations (ASEAN)-hosted aviation biofuel workshop in Bangkok. This event has generated significant interest in the topic among regional airlines. Additionally, Indonesia's government announced the world's first mandated use of biofuel for aviation with a 2% target by 2015 and 3% by 2018. In Singapore, Singapore Airlines and the Civil Aviation Authority of Singapore have awarded a contract to SkyNRG and Climate Solutions to conduct a biofuel supply feasibility study for the island nation.

6.7.2 Latin America

Brazil's Aviation Biofuel Platform was launched with Boeing and many other parties, as a follow on from the Flight Path for Aviation Biofuels in Brazil (FABB) road mapping process. The platform, led by GOL, will drive commercialization of aviation biofuel supply chains in Brazil. Notably, on Oct 23, GOL flew first Brazilian commercial biofuel flight from Sao Paulo to Brasilia on a 737-800. Progress has been facilitated by the Brazilian National Agency for Petroleum, Natural Gas, and Biofuels (ANP), who approved a hydroprocessed esters and fatty acids (HEFA) pathway for commercial jet fuel.

6.7.3 Europe

Boeing participates on the steering board of the recently launched Nordic Initiative for Sustainable Aviation (see Section 6.4 above). Via the Sustainable Aviation Fuel Users Group (SAFUG), Boeing and certain airlines engaged European Parliament in their recent contemplation of indirect land use change (ILUC). A new rule includes an amendment that incentivizes oil companies to supply jet fuel containing biofuels, which would encourage production of aviation biofuels.

6.7.4 Middle East and Africa

South African Airways and their parent Department of Public Enterprises signed an MOU for collaboration with Boeing on biofuels, becoming the first airline in Africa to formalize an effort on this topic. The Sustainable Bioenergy Research Consortium (SBRC), founded by Etihad Airways, Boeing, Honeywell-UOP, Masdar Institute of Science and Technology, and SAFRAN is midway through its development of the Integrated Seawater Energy and Agriculture System (ISEAS) which utilizes salt tolerant biomass and aquaculture waste to produce both fuel and food from arid lands.

6.7.5 North America

Together with United Airlines, Boeing and many other stakeholders completed the Midwest Aviation Sustainable Biofuels Initiative (MASBI – see Section 6.2 above), which is a multi-stakeholder aviation biofuel roadmap process focusing on the viability of sustainable aviation biofuels production in Midwest of the United States. Also, Boeing sponsored and participated in the Algal Biomass Summit in Orlando, FL. Steady progress on deploying algae for fuel, feed, food, and higher value markets was on show to over 650 participants from around the world.

Glossary

The applied definitions and acronyms in the report are mentioned in this glossary.

Definitions

1st generation biofuel	= biofuel produced from biomass that may compete with food production, degrade fresh water supply, cause deforestation and/or reduce biodiversity
2nd generation biofuel	= biofuel made from sustainable, non-food biomass such as algae, jatropha, etc.
Agricultural residues	= by-products from agriculture that are not or not well utilized
Alternative fuel	= fuel from non-petroleum source
Anaerobic digestion	= digestion in the absence of oxygen
Aromatics	= molecule with a carbon ring of unsaturated bonds
ASTM D1655	= ASTM Standard Specification for Aviation Turbine Fuels
ASTM D7566	= Standard Specification for Aviation Turbine Fuels Containing Synthesized Hydrocarbons
Barrel	= volume measure of 159 liters or 42 US gallons
Biochemical	= processing material with organisms or enzymes
Biodiesel	= alkyl esters derived from fatty acids
Biofuel	= fuel produced out of biomass
Biojet fuel	= jet fuel produced out of biomass
Biomass	= renewable biological raw material such as plants, algae, organic waste etc.
Blend	= mixing of different types of fuel
Butanol	= alcohol with a 4-carbon atom based carbon chain
Carbon footprint	= net amount of carbon dioxide emissions addressed to the applied product
Carbon neutral	= with zero carbon footprint (CO_2 emissions = CO_2 absorption)
Catalyst	= material that facilitates a chemical reaction
Cellulose	= organic compound consisting of linked D-glucose units
Cloud point	= temperature at which solids (wax) begin to form and separate from the fuel
Def Stan 91-91	= UK Defense Standard for Turbine Fuel, Aviation Kerosene Type
Density	= mass per unit volume
Distillation	= the separation of liquids by means of difference in boiling points
Drop-in fuel	= alternative fuel that is indistinguishable from conventional fuel, with no changes of aircraft, engine or supply infrastructure required
Esterification	= process to produce esters from fatty acids and alcohols, e.g. FAME and FAEE
Ethanol	= drinkable alcohol with 2 carbon atoms
FAME/FAEE	= Fatty Acid Methyl Esters/Fatty Acid Ethyl Esters – ester based biodiesels
Feedstock	= raw material such as biomass, oils, fats, coal and gas
Forest residues	= by-products from forestry industries
Fractionation	= physical separation through progressive evaporation of volatile components
Freezing point	= temperature at which a solid melts on warming
FT fuel	= fuel produced with the Fischer Tropsch process
Fuel additive	= additive to fuel to improve a certain property
Gasification	= process transforming feedstock into CO and H_2 under high temperature
Gallon	= 3.785 Liters
Hydrocarbons	= molecules made out of carbon and hydrogen, used as fuels
Hydrocracking	= cutting down carbon chains under influence of hydrogen
Hydrogenated	= raw material upgraded by hydroprocessing
Hydrotreatment	= saturating and removing impurities in hydrocarbons using hydrogen
Hydroprocessing	= upgrading of oils with hydrogen, current technology in refineries

Industry residues	= by-products from industries that are not or not well utilized
Lignin	= complex organic polymer commonly derived from wood and plant material
Marginal lands	= lands with poor soils
Methanol	= smallest alcohol with only 1 carbon atom and low specific energy
Oil-crops	= plants that produces oil, palm oil, jatropha oil, soybean oil, etc.
Paraffin	= straight-chain alkane hydrocarbons with general formula C_nH_{2n+2}
Polymerization	= chemical process bonding together multiple small molecules
Pyrolysis	= heating in absence of oxygen resulting in thermal decomposition
Solid biomass	= biomass in solid state, such as wood, switch grass, etc.
Specific energy	= amount of energy per unit weight or volume
SPK	= Synthetic Paraffinic Kerosene, jet fuel substitute lacking aromatic compounds
Sustainable biomass	= renewable and environmentally friendly biomass
Switch grass	= a perennial grass
Syngas	= mixture of hydrogen and carbon monoxide
Thermal stability	= measure for the chemical stability at elevated temperature
Waxes	= solid long-chain carbon molecules

Acronyms

AEMP	= Annual Emissions Monitoring Plan
AER	= Annual Emissions Report
AFRL	= Air Force Research Laboratory (USA)
ASTM	= American Society of Testing and Materials (USA)
ATA	= Air Transport Association (USA)
BTL	= Biomass to Liquids (Fischer-Tropsch process)
BTU	= British Thermal Unit
CAA	= Civil Aviation Authority
CAAFI	= Commercial Alternative Aviation Fuels Initiative (USA)
CO_2	= Carbon Dioxide
CTL	= Coal to Liquids (Fischer-Tropsch process)
DLA	= Defense Logistics Agency (USA)
DOE	= Department of Energy (USA)
EC	= European Commission
EPA	= Environmental Protection Agency (USA)
ETS	= Emissions Trading Scheme
EU	= European Union
EUA	= European Union Emission Allowance
EUAA	= European Union Aviation Emission Allowance
FT	= Fischer-Tropsch process
FAA	= Federal Aviation Administration (USA)
FAE	= Fatty Acid Ester
FAEE	= Fatty Acid Ethyl Ester
FAME	= Fatty Acid Methyl Ester
GE	= Gasoline Equivalent
GHG	= Greenhouse Gas
GTL	= Gas to Liquids (Fischer-Tropsch process)
HEFA	= Hydroprocessed Esters and Fatty Acids
HRJ	= Hydroprocessed Renewable Jet fuel
ICAO	= International Civil Aviation Organization
IEA	= International Energy Agency
LCA	= Lifecycle Analysis
LGE	= Liters of Gasoline Equivalent
MJ	= Megajoule
OEM	= Original Equipment Manufacturer
PARTNER	= Partnership for Air Transportation Noise & Emission Reduction
PPP	= Public Private Partnership
RED	= Renewable Energy Directive (EU)
RFS	= Renewable Fuel Standard (USA)
RSB	= Roundtable on Sustainable Biofuels
SPK	= Synthetic Paraffinic Kerosene
SWAFEA	= Sustainable Way for Alternative Fuels and Energy in Aviation
USAF	= United States Air Force

Acknowledgements

IATA would like to express its appreciation to the following experts for their valuable contributions to this report:

Robert Arendal – NISA
Michel Baljet – IATA
Robert Boyd – IATA
César Velarde Catolfi-Salvoni – ITAKA
Frédéric Eychenne – Airbus
Andreas Feige – International Sustainability & Carbon Certification
Marcelo de Freitas Gonçalves – Embraer
Rolf Hogan – Roundtable on Sustainable Biomaterials
Jane Hupe – International Civil Aviation Organization
Angelica Hull – Swedish Biofuels
Siegfried Knecht – aireg
Fokko Kroesen – KLM
Dirk Kronemeijer – SkyNRG
Jorin Mamen – IATA
Robert Malina – Massachusetts Institute of Technology
Kyriakos Maniatis – European Commission
Darrin Morgan – Boeing
Philippe Novelli – International Civil Aviation Organization
Brian Pearce – IATA
Matthew N. Pearlson – Massachusetts Institute of Technology
Stefanio Pescarolo – Biochemtex
Thomas Rötger – IATA
Lukas Rohleder – aireg
Mark Rumizen – Federal Aviation Administration
Jimmy Samartzis – United Airlines/MASBI
Pam Serino – Defense Energy Support Center
Maarten van Dijk – SkyNRG
Mitch R. Withers – Massachusetts Institute of Technology
Alexander Zschocke – DLH Deutsche Lufthansa

to order:

www.iata.org/publishing

custserv@iata.org

+1 800 716 6326

+1 (514) 874 9659

Follow us on Twitter: www.twitter.com/iata

Join us on Linkedin: www.iata.org/linkedin

Follow us on Youtube: www.youtube.com/iatatv

Printed in Canada

ISBN 978-92-9252-259-9