



IATA 2015 Report on Alternative Fuels

Effective December 2015

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Alternative Fuels Foreword 2015

Dear readers,

In 2008, the aviation industry did what no other transport sector had done before – it set targets for cutting its CO₂ emissions. They are well known. A short-term efficiency goal, a mid-term cap on net emissions and an ambitious long-term goal to halve CO₂ from aviation by 2050.

Sustainable alternative fuels will play a significant role in achieving the industry's long-term emissions reduction goal. Starting from a relatively modest base today, these low-carbon fuels will provide a great deal of our needs in the future. More than 2,000 commercial flights have taken place so far. Over twenty airlines have made those flights a reality and a number of them have shown outstanding leadership by committing to the long-term development of this important energy supply. Significant equity stakes and forward purchase agreements have been signed and we are certain that there are more to come.

While some suggest the alternative aviation fuel story is taking a long time, we should remember that we flew the first commercial aircraft test flight on biofuel in just 2008. Seven years later and we will have alternative fuel on regular daily flights by early next year. It is an impressive achievement, considering that the fossil fuel industry had over 100 years to establish itself as the large scale industry it is today.

With nine billion people expected to be living on our earth by 2050, waste is always going to be a challenge. But we can use that waste to generate alternative fuels for our flights. We can help solve the two problems at once. Further there are other promising initiatives being explored and developed, which you can read more about in this report.

Although no new production pathways were approved by ASTM International in 2015 it is exciting to note that over 15 new pathways are currently in the approval process. It is expected that in 2016, additional methods to produce alternative jet fuel will be approved adding additional supply options and enhancing deployment opportunities.

To discover more about the certification of new fuels, important progress towards harmonizing sustainability and accounting standards, multi-stakeholder initiatives, direct airline efforts and more, I invite you to read this report. I would like to sincerely thank aviation industry specialists, manufacturers and governmental bodies for their contributions.

I wish you happy reading.

Michael Gill
Director Aviation Environment
International Air Transport Association



Summary

The alternative jet fuel sector has continued to progress in 2015. A total of 22 airlines have now used alternative fuel for over 2000 commercial flights. For an industry that remains young, this is impressive, particularly when less than a decade ago the entire concept was labeled as hypothetical.

In September 2013, the 38th Session of the ICAO Assembly reaffirmed the role of ICAO to facilitate and support States and stakeholders in their efforts to stabilize their emissions at 2020 levels. This Assembly also agreed on the development of a global market-based mechanism for international aviation. This has led to increasing amounts of work being conducted within ICAO's Committee on Aviation Environmental Protection and the creation of the Alternative Fuels Task Force. In many instances airline representatives are contributing valuable knowledge in to the CAEP process which is developing a regulatory and logistical foundation for increased and global alternative fuel use.

This ICAO activity is elevating the imperative to address incompatibilities with regionally focused sustainability and alternative fuel accounting standards. This

is important work and presented in some detail in Chapter 2.

This is not to say other activity has slowed. In fact, 22 new initiatives have commenced in 2015 taking the total number of multi-stakeholder initiatives to close to 100. While price remains a challenge, especially from the sharp decline in energy prices, there is growing evidence that with the support of appropriate policy mechanisms, innovative business cases can be developed to enable production to evolve from demonstration scale to commercial scale.

Chapters 5 and 6 highlight some particularly impressive projects and notable developments contributing to the industry efforts for wider commercial deployment of alternative jet fuel.

With a number of new production pathways currently in the ASTM International approval process 2016 is likely to certify some additional methods for producing drop-in alternative jet fuel. With the prospect of additional supply options, regular supply and use by an airline, and increasing policy momentum from States, 2016 has the potential to be a significant year in the evolution of alternative jet fuel use in aviation.

Quick Facts

- Early 2016 should see the first commercial production and use of alternative jet fuel. AltAir should be supplying United Airlines at Los Angeles Airport a regular supply of alternative jet fuel – a symbolic and significant achievement.
- Canada's Biojet Supply Chain Initiative (CBSCI) is aiming to help enable carbon neutral growth in the Canadian aviation sector through downstream integration of sustainably certified biojet fuel in a comingled airport fuel supply system.
- Fedex has joined the list of airlines committing to alternative jet fuel off-take agreements using Red Rock Biofuels as their supplier.
- China's first commercial passenger flight was performed by Hainan Airlines with the fuel produced by Sinopec using waste cooking oil.
- South African Airways launched their project Solaris which will produce alternative jet fuel from tobacco plants.
- IATA, with the support of a number of industry partners held a dedicated symposium for alternative fuels, immediately following the traditional IATA fuel forum.

Recommendations

- Governments should level the playing field by making alternative jet fuel incentives equivalent with road biofuels. Aviation has no alternative at this stage, to a liquid drop-in fuel where the road transport sector has other non-liquid fuel options available such as electricity and fuel cells. The level policy playing field needs to be applied with medium to long-term policy certainty, allowing debt and equity investors to make plant financing decisions.
- Pursue a pathway and strategy for harmonization of sustainability and alternative fuel accounting regulations. The current regional patchwork of regulations needs to evolve into globally homogeneous standards. This will become increasingly clear and important as the development of the global market based mechanism develops with important advances expected in 2016.
- Support research aimed to lower feedstock costs and new production processes – aviation is keen to access as many sources of alternative fuel as possible, as long as sustainability criteria are maintained.
- Incentivise airlines to use SAF from an early stage to help boost the market and catalyse investment.
- De-risk public and private investment in production – production grants have been effective and guaranteeing the building of production facilities can help start putting bioenergy on a similar footing as fossil fuel.
- Foster local opportunities (localised scoping studies and roadmaps are effective) – there may be local sustainable alternative energy industries that could be fostered, providing economic benefits and bringing the green economy to parts of the world not currently included. Japan and South Africa in this report are strong examples.

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Report on Alternative Fuels

1. Overview of Alternative Fuels in 2015

1.1 Chapter summary

The alternative jet fuels sector has made strong progress in 2015 with action and new initiatives in all areas. More than 2000 flights have now occurred on alternative fuels by over 20 different airlines. A highlight during the year was United Airlines large off-take agreement and \$30 million USD equity investment in Fulcrum Bioenergy.

An increasing number of countries are engaged in strategies to develop a sustainable aviation fuel sector with a particular focus on removing barriers to commercialization. Much of this work is being supported by regional or industry roadmaps and policy makers are being consistently alerted to the need for a 'level playing field' concerning alternative fuel incentives for the road sector and aviation.

While the alternative jet fuel sector is maturing, plenty of work still needs to be done to see the wide-scale commercial deployment that will deliver significant CO₂ reductions. For many airlines the emphasis on conducting a one-off demonstration or promotional flights is giving way to investing time and resources in developing the operating foundations for this new industry. This includes valuable work being conducted within ICAO's Committee on Aviation Environmental Protection (CAEP), in particular, the goal to provide a global view on the future use of alternative fuels and on the associated changes in life cycle emissions, in order to assess the progress towards achieving ICAO's Member States' aspirational goal to stabilize aviation emissions at their 2020 level.

In 2015 over 20 new multi-stakeholder initiatives were established covering all regions of the world. The Alternative Fuels Task Force completed its work modelling the potential CO₂ reductions that can be achieved from alternative fuels and designing a life cycle anal-

ysis methodology for use by a potential market based mechanism. Despite a number of significant achievements, economics remains a challenging barrier to overcome for initial deployment, particularly in the face of current weak oil prices. Encouragingly, efforts are not slowing to address and solve some of these commercialization challenges, and the 1st IATA Alternative Fuel Symposium, held in Cancun, Mexico, was a symbolic gathering world experts, as well as both the demand and supply side for alternative fuels.

IATA gratefully acknowledges Jane Hupe and Ted Thrasher at ICAO for their assistance in preparing this chapter.

1.2 Introduction

In 2009, the International Civil Aviation Organization (ICAO) organized the Conference on Aviation and Alternative Fuels, during which ICAO Member States endorsed the use of sustainable alternative fuels for aviation as an important means of reducing aviation emissions. This turning point, where consideration of alternative fuels became global, further led to the inclusion of recommendations in the Resolution on Aviation and Climate Change, Resolution A37-19, adopted by the 37th ICAO Assembly, for States to consider policies and measures to support and accelerate, as appropriate, the development and deployment of such fuels as part of the basket of measures to reduce aviation's impact on climate.

Also in 2009, ASTM International approved the Fischer-Tropsch process as the first process for producing alternative jet fuel, crowning the effort undertaken to introduce "drop-in" alternative fuels in aviation¹, with the support of the United States' Commercial Aviation Alternative Fuels Initiative (CAAFI) and the US Air Force.

1. A drop-in fuel is a substitute for conventional jet fuel, which is fully compatible, mixable and interchangeable with conventional jet fuel. Such an alternative fuel does not require any adaptation of the aircraft and or infrastructure, and does not imply any restriction on the domain of use of the aircraft.

Following these milestones, initiatives have multiplied worldwide to promote, support or initiate the development, deployment or use of sustainable alternative fuels in aviation. The approval of HEFA fuels (made through hydroprocessing of vegetable oils and animal fats) by ASTM in September 2011 triggered the take-off of the first commercial flights using alternative fuels and, to date, there have been more than 2000 flights performed by over 20 different airlines.

This contribution heavily supported by ICAO constitutes an updated overview of the major achievements and progress made in 2015.

1.3 Commercial production and use of sustainable alternative fuels

Numerous commercial flights were operated by airlines following the approval of HEFA fuel in September 2011. These were important to both demonstrate and promote this advance in energy options. However, commercial availability of these fuels has remained limited, largely due to the price being uncompetitive with convention fossil kerosene, especially with production facilities being at demonstration or relatively smaller scale.

Alternative fuel production is a young industry. All aspects from technology improvements, feedstock development, policy initiatives, production plant efficiency, industry understanding, and optimal commercial structures are advancing quickly. More recently there have been promising signals that genuine commercial production of sustainable alternative fuels will occur in the next years. In 2013, United Airlines announced a purchase agreement with AltAir for HEFA fuel to be produced in the Bakersfield refinery that AltAir is retrofitting. The plant should start production in 2016, with a nominal production capacity of 90 kt/y of renewable diesel and jet fuel.

The most significant commercial event of 2015 also involved United Airlines. In June, United announced an agreement to make a USD \$30 million equity investment in Fulcrum Bioenergy. Fulcrum's technology converts municipal solid waste (MSW) into renewable jet fuel. This represented the single largest investment by a U.S. airline in alternative fuels. Additional to the investment, United and Fulcrum have entered into an agreement that contemplates the joint development of up to five projects located near United's hubs expected to have the potential to produce up to 180 million gallons of fuel per year.

Airlines/Fuel producers agreements

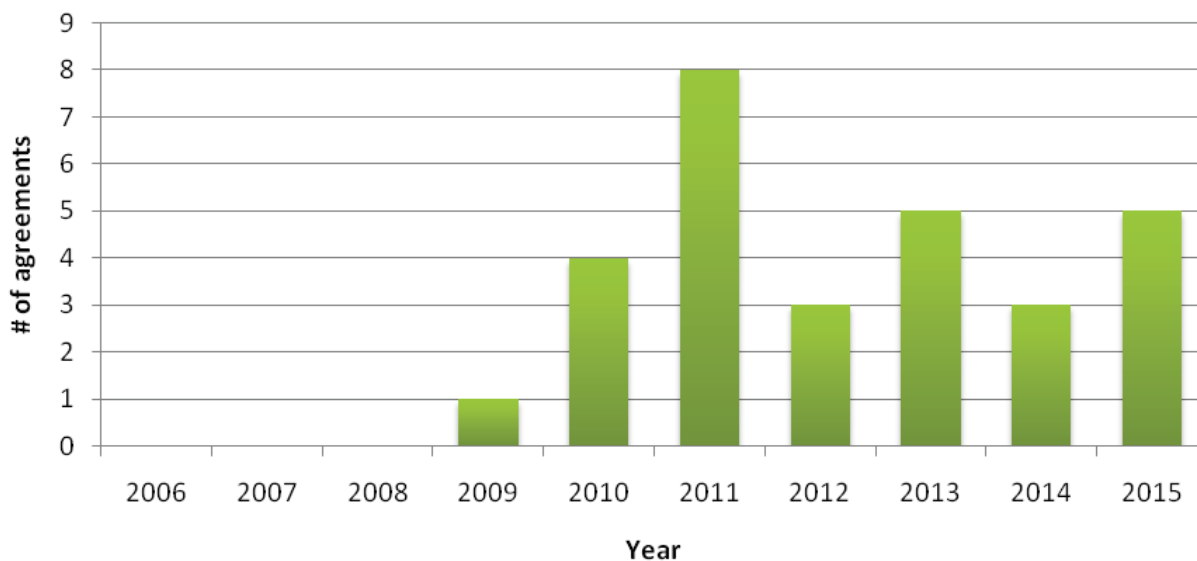


Figure1 – Agreements between airlines and fuel producers since the first certification in 2009

In total there were 5 new airline/fuel producer agreements. In addition, major aircraft manufacturers, including Airbus, Boeing, and Gulfstream have been very active in developing regional partnerships.

1.4 Initiative for the development and deployment of alternative fuels

As noted in the previous edition of this report, a remarkable tendency, besides this cooperation between airlines and fuel producers, is the emergence and multiplication of stakeholders' initiatives and cooperation agreements worldwide. By the end of November 2015, 22 new multi-stakeholder initiatives and projects had been announced for 2015. [Figure 2] These initiatives have a wide range of purposes, including networking and coordination of national stakeholders for the development of alternative jet fuels, international cooperation, research and development, assessment of potential for production or setting-up production value-chains.

In 2015 alone, there were many important activities regarding State's initiatives. A few of the year's highlights include:

- Various research activities occurred at Masdar's Sustainable Bioenergy Research Consortium, including promising studies involving halophytes.
- The SkyNRGFly Green Fund was launched to fund investments in biofuel use and development of sustainable alternative fuel supply chains in the Nordic region.
- Project Solaris, launched in South Africa in 2014, received certification from the Roundtable on Sustainable Biomaterials (RSB). The partners have announced plans for coordination of a celebratory demonstration flight.
- Indonesia and the United States have signed an MOU to promote the use of sustainable fuels in aviation and encourage further research cooperation between the two countries.
- the creation of a stakeholders action group in Japan aiming at developing a roadmap to establish an alternative jet fuel supply chain in Japan by 2020, with the target of having commercial flights using biofuels for the Tokyo Olympic games.

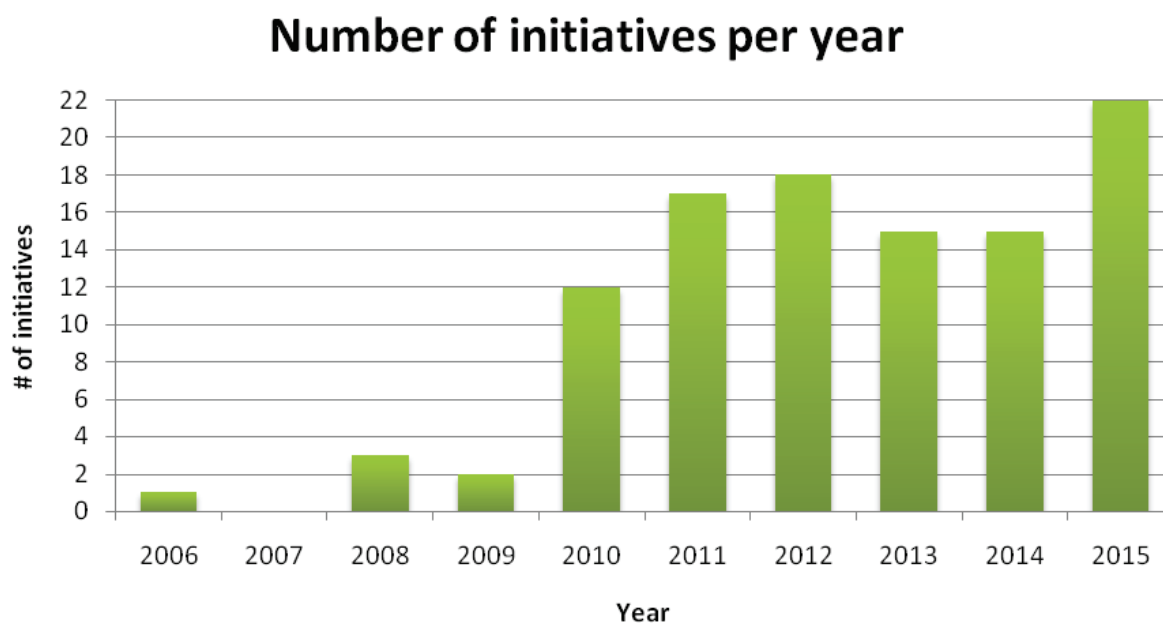


Figure 2 – The highest number (22) of new initiatives was recorded in 2015

**Initiatives by Type
(Active in 2015)**

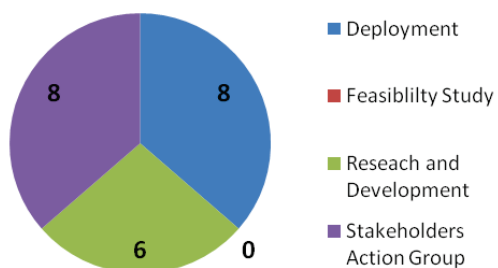


Figure 3 – Initiatives by type in 2015

Initiatives by Funding Source (Active in 2015)

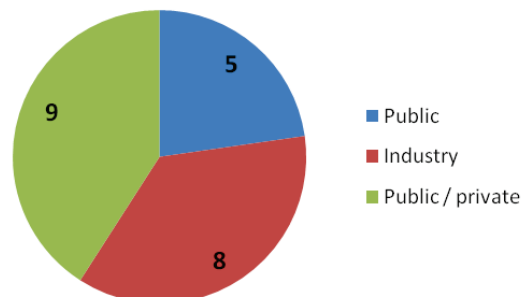


Figure 4 – Initiatives by funding source in 2015

**Initiatives by Region
(Active in 2015)**

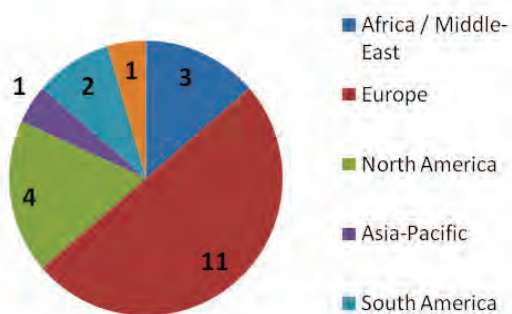


Figure 5 – Initiatives by region in 2015

**News Announcements in
2015**

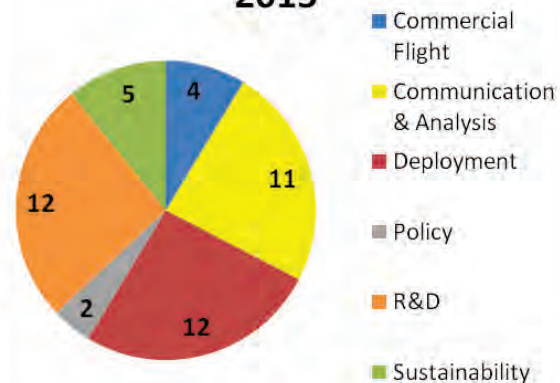


Figure 6 – News announcements in 2015

1.4.1 Key milestones in the commercialization of alternative jet fuel

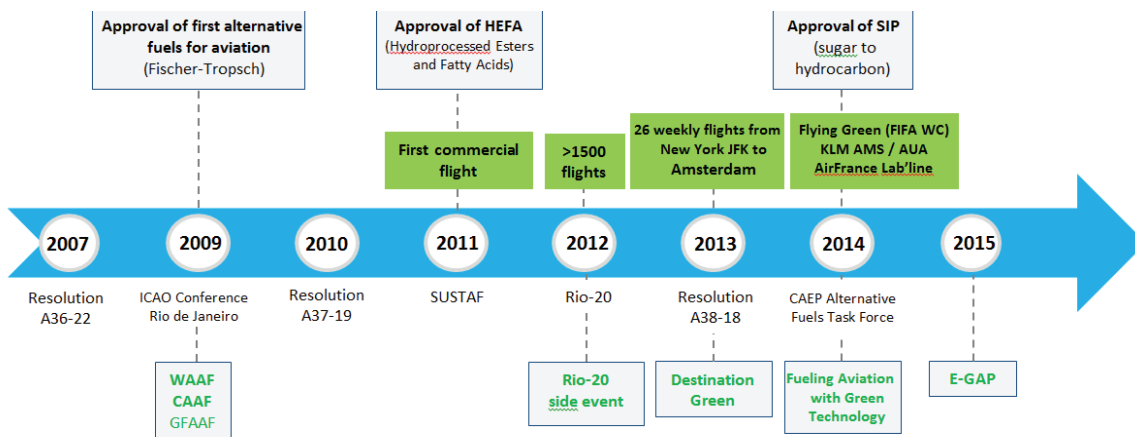


Figure 7 – The time line of alternative jet fuel development

1.5 The challenges

Perhaps the most obvious challenge is the difficult economic conditions facing new alternative jet fuel producers. Between 2011–2013 the Brent crude oil price averaged over \$100 per barrel each calendar year. The modest weakening of the oil price in 2014 has been overshadowed by the dramatic decline in the Brent crude price during calendar 2015. With an oversupply and no agreement from OPEC to manage production, Brent crude fell below \$40 per barrel for the first time in many years. On the one hand this has provided welcome assistance for the aviation industry to improve profitability, however, it has made alternative jet fuel business cases more difficult to gain economic approval and obtain necessary finance.

The cost of producing alternative jet fuel is not defined by one single price. There are different feedstocks, different conversion technologies, different economic structures which imply a range of possible costs to produce alternative jet fuel. This is not different to the lifting costs of convention fossil crude oil, which in some regions may be as low as \$15 per barrel, while in other geographies such as deep water wells could be over \$80 per barrel. It is irrefutable that both some alternative jet fuel and some fossil oil production is not economic at <\$40 per barrel. The traditional response to these price changes is a supply side response, ultimately bring the oil market back into equilibrium

and an associated increase in the price. While this rebalancing will occur, it is feasible that oil remains at a lower price than in recent years. This means that alternative jet fuel producers need to be competitive in an environment of relatively cheap oil. While this is a challenge, it can also be viewed as a positive for the economic sustainability of this new industry.

Effective policy will remain an important enabler for bringing new technologies to commercial scale. The experience with the general development of advanced biofuels shows that the demonstration step and the scale-up from the laboratory or demonstration facility to the commercial plant are usually big challenges for start-up companies which often experience financial stress during these phases.

In the longer term, pursuing research to increase efficiency and decrease costs for both conversion processes and feedstock is key to bridging the price gap with fossil fuels. Work on feedstock is also important for making sufficient volumes of sustainable feedstock available for long term, large-scale deployment. This includes increasing yields and developing innovative feedstock, such as algae.

Due to the global nature of international aviation, sustainability is a topic for which increased harmonization and collaboration between countries would yield benefits to facilitate the deployment of alternative fuels.

1.6 Achievements under ICAO

ICAO was also tasked by the 38th Assembly to provide a global view on the future use of alternative fuels and on the associated changes in life cycle emissions, in order to assess the progress towards achieving ICAO's Member States' aspirational goal to stabilize aviation emissions at their 2020 level. Assessing fuel life cycle emissions is a particular topic for which increased harmonization amongst aviation stakeholders is important in order to acquire a shared understanding of the potential benefit of alternative fuels. Therefore, the Alternative Fuels Task Force (AFTF) was created within the ICAO technical body on environment, the Committee on Aviation Environmental Protection (CAEP). CAEP is the committee that assists the ICAO Council in formulating policies and adopting new standards and recommended practices in the field of environment. It undertakes specific studies with groups of technical experts nominated by States and international organizations. The AFTF is tasked to develop a methodology to assess fuels life cycle emissions and will apply it to quantify the emissions associated to a projection of alternative jet fuels production to 2050. The task force gathers 80 representatives from 16 member States and 8 observer organizations. The results will be delivered to the 39th Session of the ICAO Assembly in 2016, and included in ICAO's environmental trends assessment for international civil aviation.

The 38th Assembly also agreed on the development of a global market-based measure (MBM) for international aviation for decision by the 39th Assembly in 2016. The AFTF was requested to make proposals on an approach to assess lifecycle emissions from alternative fuels for use in the monitoring, reporting and verification system of the MBM. This work has been completed in 2015 and will be presented at the CAEP meeting in February 2016. Some additional detail is presented in Chapter 2.

1.7 Conclusion

Establishing any new industry takes considerable time and effort. Alternative jet fuel is no different. For a young industry the incremental progress has been significant. Aviation has achieved successful steps in bringing sustainable alternative fuels to technical maturity for use in commercial aircraft and numerous flights have demonstrated that the fuels can be safely and regularly used. Despite the challenging economic backdrop of a low oil price, growth in initiatives to set up production or assess the feasibility of such production has not slowed. The work within ICAO by the Alternative Fuels Task Force is making a key contribution to understanding the future potential of alternative jet fuel and aiding informed decision-making. Regular commercial production will be a feature of 2016 and will help establish a platform for the next stage of growth.

2. Standard harmonisation and a future market based mechanism

2

2.1 Chapter Summary

The 2013 ICAO resolution to develop a global market-based measure for aviation has created a genuine motivation to assess the compatibility of existing sustainability and accounting framework for sustainable alternative jet fuel. This chapter builds on thoughts from the 2014 Report on Alternative Fuels, providing factual information behind the future market based mechanism process and explores some of the work occurring on pathways towards sustainability and accounting harmonisation for alternative jet fuel. The author gratefully acknowledges the contributions from Michel Adam, Andreas Hardman and Thomas Roetger from IATA to this Chapter.

2.2 Alternative fuels and a future market based mechanism

Alternative fuels are a key element of aviation's climate change strategy. IATA recognizes the need to address the global challenge of climate change and adopted a set of ambitious targets to mitigate CO₂ emissions from air transport:

- An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020;
- A cap on net aviation CO₂ emissions from 2020 (carbon-neutral growth);
- A reduction in net aviation CO₂ emissions of 50% by 2050, relative to 2005 levels.

The aviation industry is confident that technology, including sustainable alternative fuels, operations and infrastructure measures will provide the long-term solution for aviation's sustainable growth. However, some form of market-based measure (MBM) will be needed to fill the remaining emissions gap.

2.2.1 Milestone decision at the 38th ICAO Assembly

In 2013, the 38th ICAO Assembly concluded with a milestone resolution on climate change. In Assembly Resolution A38-18, the 191 members States of ICAO formally decided to develop a global market-based measure for international aviation, effective from 2020.

The decision came a few months after IATA member airlines urged governments to support a single global MBM to achieve carbon neutral growth post-2020. In June 2013, at the IATA Annual General Meeting, IATA member airlines noted that success in managing aviation CO₂ emissions required a comprehensive package of technological, infrastructure and operational measures, complemented by a global MBM to fill any gap in reaching the industry's goal of capping the sector's net emissions at 2020 levels.

In the lead-up to the 38th Assembly, the global aviation industry, through the Air Transport Action Group (ATAG), also recommended the adoption of a global MBM as part of a broader package of measures. The aviation industry outlined a set of principles for such a measure, including the need to preserve fair competition and to minimize competitive distortions and administrative complexity. The industry emphasized that a global MBM should be cost-efficient and that it should not be designed to raise general revenues or to suppress demand for air travel.

2.2.2 A market based measure

The Assembly requested that the Council finalize the work on the possible options for a global MBM scheme, for decision, at the 39th Session of the Assembly in 2016.

The ICAO Council established the Environment Advisory Group (EAG) to oversee this work and requested

ICAO's Committee on Aviation Environmental Protection (CAEP) to create a dedicated task force, the Global MBM Technical Task Force (GMTF), to provide support. While EAG focuses on the political aspects of a GMBM, the GMTF deals with the technical questions and analysis in support of EAG discussions.

A single global scheme will help ensure environmental integrity by covering virtually all commercial aviation emissions. It will also avoid market distortion which could be caused if a patchwork of measures were applied in different countries or regions of the world.

2.2.3 An important part of any scheme

The industry has set out some criteria it considers important in any MBM

- It should maximise environmental integrity (to ensure that all airlines face the same environmental stringency)
- It should be cost-efficient (both to the industry and to governments)
- It should not be used to raise general revenues or suppress the demand for air travel (which breeches the Chicago Convention and does not meet the needs of developing nations which need aviation connectivity to power economic growth).
- It must minimise competitive distortion (in aviation, this is not a simple task, as competition does not just occur between airlines flying the same city-pair route).
- It should be easy to implement and administer (both for airlines to comply with and for government agencies to verify).

One of the main tasks of GMTF is the development of recommendations regarding monitoring, reporting and verification (MRV) for aircraft operator emissions under a future global MBM, including incorporation of operators' use of sustainable alternative fuels. The GMTF is also working on the issue of how to attribute the GMBM benefits of alternative fuel use to the airline buying it, including consideration of the point in the MRV process the emissions savings from alternative fuels meeting the agreed lifecycle emissions and sustainability criteria should be accounted for relative to the operators' total emissions and emissions obligations under the GMBM.

In September 2015, the aviation industry sent an open letter to Governments urging them to work together

with the industry and civil society to push this process forward and shape a ground-breaking market-based measure that will, for the first time, enable a single global sector to stabilise its emissions from 2020. [www.enviro.aero/openletter]

2.3 Global harmonization of sustainability standards and biofuel accounting methods

2.3.1 Sustainability

As described in the previous section, the use of sustainable alternative fuels is a measure for reducing greenhouse gas emissions that is planned to give rise to incentives for aircraft operators under the future global MBM currently being developed in ICAO.

There is wide agreement that alternative fuels have to meet some sustainability criteria in order to be eligible for recognition under any incentive scheme including a global MBM. However, a wide variety of sustainability criteria is currently in use in different countries.

Soon after biofuels had been introduced in road transport and awareness had grown regarding negative effects of some first-generation biofuels, regulators in several countries as well as voluntary initiatives established standards covering various aspects of sustainability, mainly greenhouse gas reductions, impact on land and water use and protection of biodiversity and high carbon stock lands. The most widely applied examples of regulatory standards are the Renewable Energy Directive (RED) in the EU and the Renewable Fuels Standard (RFS) in the US. The voluntary standard established by the Roundtable on Sustainable Biomaterials covers the most comprehensive scope of environmental, societal and economic sustainability criteria. Compliance with the RED can be certified through one of 17 voluntary standards; amongst them ISCC has certified the highest number of biofuel and feedstock producers. Descriptions of these standards and their application can be found in various previous editions of the IATA Report on Alternative Fuels.²

Unfortunately, there are considerable differences between these standards in terms of the sustainability criteria considered. In addition, they apply methods for lifecycle analysis of greenhouse gas emissions

2. <http://www.iata.org/publications/Pages/alternative-fuels.aspx>

that are not directly comparable with each other. As a new CAEP cycle commences in 2016, increasing emphasis will be placed on considering what sustainability criteria are important for alternative fuel eligibility within the context of an MBM. Furthermore, defining the minimum ambition level will require effective evaluation and consultation. This work is expected to be carried out within ICAO's Alternative Fuels Task Force in the next years.

2.3.2 Comparison of key aspects of voluntary schemes

The table below summarises some key aspects of a sample of five voluntary sustainability schemes, which facilitates the identification of similarities and differences.

Table 1: Comparison of voluntary schemes – key aspects

Aspect	2BSvs	Bonsucro EU	ISCC EU	RSB EU RED	RSPO-RED
Scope					
Feedstock coverage	All	Sugarcane	All	All	Palm Oil
Recognition of other EU schemes					
Mandatory Sustainability criteria					
Coverage of RED land criteria					
Soil, water and air protection					
Social					
Economic					
Chain of Custody (CoC) and Traceability					
Mass balance	Continuous	Continuous	Deficit - 3 months balancing period	Continuous	Continuous
Further CoC options	No	Physical shipment, Book-and-claim	Physical segregation	Identity of product preserved, Segregation of product	Segregated, Identity Preserved and Book-and-claim
Unique ID number for consignment					
Coverage of tracked information through the supply chain	Low	Medium	High	High	High
Auditing					
Unit of certification	First gathering point and supply base	Mill and supply base	First gathering point and supply base	First gathering point and supply base	Mill and supply base
Certificate validity	5 years	3 years	1 year	3 months – 2 years depending on risk class	5 years
Aspect	2BSvs	Bonsucro EU	ISCC EU	RSB EU RED	RSPO-RED

Source: Ecofys report for IATA 2014


2.3.3 Setting the sustainability ambition level

The figure below summarises the sustainability coverage of the national legislations of the EU and the USA, and some voluntary schemes. It can be seen that they both include “common sustainability” requirements (highlighted in green). These relate to restrictions on land conversion (biodiversity protection and carbon stock protection), as well as minimum GHG savings requirements. The inclusion of criteria covering wider environmental impacts, or social and

economic issues is currently not covered by national legislation (highlighted in red), and is only mandatory in some voluntary schemes.

RSB and RSPO set the highest level of sustainability ambition as they are the only schemes that include all of the sustainability criteria in a mandatory way, while 2BSvs only covers the common sustainability requirements. Bonsucro and ISCC include sustainability criteria beyond the common requirements, however the schemes include exemptions for some/all of the criteria (highlighted in yellow).

Table 2: Overview comparing the sustainability requirements of the national legislation and voluntary schemes under review.



Sustainability criteria	National legislations		Voluntary schemes				
	RED	RF52	2BSvs	Bon-sucro	ISCC	RSB	RSPO
Economic criteria	Not included	Not included	Not included	Partially included	Not included	Included	Included
Social criteria	Not included	Not included	Not included	Partially included	Partially included	Included	Included
Soil, air & water protection	Not included	Not included	Not included	Partially included	Partially included	Included	Included
Land conversion restrictions - biodiversity & carbon stock protection	Included	Included	Included	Included	Included	Included	Included
GHG savings	Included	Included	Included	Included	Included	Included	Included

Common sustainability criteria coverage

Included
 Partially included
 Not included

2.3.4 A meta-standard

Defining a “meta-standard” or framework that different national standards would have to meet means that only biofuels certified by one of the qualified national standards would be recognized for their greenhouse gas emissions under the ICAO scheme. This meta-standard would ideally be elaborated by an international multi-stakeholder group. In addition to a basic (minimum) level defining the requirements for recognition under the ICAO global MBM, higher levels could also be established for additional voluntary certification of producers and/or operators.

With a set of proposed principles and criteria for a potential Meta-standard, several options can now be identified with which to structure a Meta-standard. These options would reflect differentiated levels of sustainability ambition, and could take into account the views of the airline industry.

Developing an acceptable minimum ambition level will be of key importance, but also ensuring the mechanism agreed contains the scope to recognise and appropriately incentivise higher levels of ambition will be important.

12 principles and associated criteria for a potential alternative jet fuel sustainability meta-standard

Principle 1. Legality

Criterion 1.1 Sustainable alternative aviation fuel shall comply with all applicable national and local laws and regulation.

Principle 2. Greenhouse gas emissions

Criterion 2.1 Sustainable alternative aviation fuel shall achieve net greenhouse gas emissions reductions on a life-cycle basis.

Principle 3. Carbon stock conservation

Criterion 3.1 Sustainable alternative aviation fuel shall not be made from biomass obtained from land with high carbon stock.

Principle 4. Biodiversity conservation

Criterion 4.1 Sustainable alternative aviation fuel shall not be made from biomass obtained from land with high biodiversity value.

Criterion 4.2 Basic ecosystem services in critical situations shall be maintained or enhanced.

Criterion 4.3 Biodiversity within the area of operation shall be maintained or enhanced.

Criterion 4.4 Biodiversity within the area of operation shall not be compromised by the use of genetically modified plants, micro-organisms or algae.

Principle 5. Soil conservation

Criterion 5.1 Good agricultural practices shall be implemented to maintain or enhance soil physical, chemical, and biological conditions.

Principle 6. Sustainable water use

Criterion 6.1 Good agricultural practices shall be implemented to maintain and improve water quality.

Criterion 6.2 Good agricultural practices shall be implemented to use water efficiently, and to avoid the depletion of surface or groundwater resources beyond replenishment capacities.

Principle 7. Air quality

Criterion 7.1 Open-air burning as part of land clearance, or the burning of agricultural residues and

wastes shall not be practised, unless there are no viable alternatives.

Criterion 7.2 Air pollution emissions shall be minimised.

Principle 8. Use of chemicals, wastes and by-products

Criterion 8.1 Chemicals, wastes or by-products arising from fuel production shall be stored, handled and disposed of responsibly to safeguard the environment and to minimise the risk to people.

Principle 9. Land and Water rights and Community engagement

Criterion 9.1 Sustainable alternative aviation fuel-operations shall respect existing land rights and land use rights.

Criterion 9.2 Sustainable alternative aviation fuel-operations shall respect the existing water rights of local and indigenous communities.

Criterion 9.3 Sustainable alternative aviation fuel-operations shall only be established with the free, prior and informed consent of land and water users or owners.

Principle 10. Human rights and Labour rights

Criterion 10.1 Human rights and labour rights governing child labour, forced labour, discrimination, freedom of association and the right to organise and bargain collectively shall not be violated.

Principle 11. Local food security

Criterion 11.1 Sustainable alternative aviation fuel-operations shall not adversely impact the human right to adequate food and shall not adversely impact food security in food insecure regions.

Principle 12. Rural, Social and Economic development

Criterion 12.1 In regions of poverty, aviation fuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.

Source: Ecofys and the Round Table on Sustainable Biomaterials

2.3.5 Accounting

For a smooth uptake of sustainable fuels in aviation under the ICAO global MBM scheme it is also essential that user-friendly accounting methods are

put in place. While the biofuel flights that have taken place so far were all demonstration flights using dedicated and highly controlled batches of biofuel, this is expected not to happen any longer in future, when whole airports ("bioports") will be provided with

sustainable fuel blends through their common distribution system. In this case, and due to the drop-in property of all current sustainable alternative jet fuels, it is no longer possible to physically track the alternative fuel content through the logistics chain down to a specific aircraft. Instead, the only practical method to account for an operator's use of sustainable alternative fuels would be through purchase and delivery records. This principle has been adopted e.g. by the European Commission in the Monitoring and Reporting Guidelines (MRG) applicable for the EU Emissions Trading Scheme (ETS)³.

Climate change and the related greenhouse gas emissions are a global effect. It is thus the fact that a certain

amount of sustainable fuel is supplied for use in aircraft that is relevant for emissions reduction, no matter by which aircraft or on which route the fuel was burned.

2.3.6 Chain of custody accounting approaches

Different chain of custody approaches can be distinguished that vary in their flexibility and in the final 'claims' that can be made. Within each approach there are design choices that can be made. The following sections describe the key characteristics that define each of the chain of custody approaches.

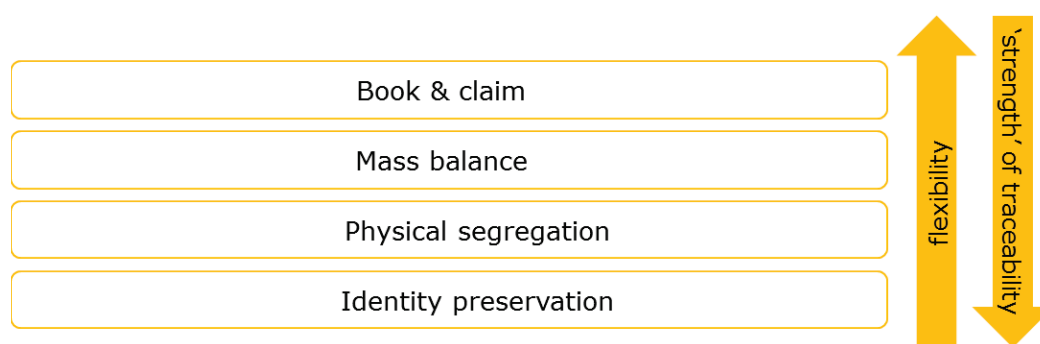


Figure 8 – Different chain of custody approaches

A book-and-claim system for sustainable fuels is therefore well adapted to the situation in aviation. "Book-and-claim" designates a system in which operators who get delivered sustainable fuel receive certificates allowing them to claim a benefit such as an incentive under a national scheme or recognition under the proposed ICAO global MBM. In order to prevent fraud and double counting in the system, these certificates must of course be unique and protected against duplication.

In a scheme with a geographically limited scope, additional indications, such as the location of fuel delivery, can be required to ensure that only sustainable fuel used in the area of validity of the respective scheme is receiving benefits under that scheme. This is e.g. the case in the European MRG, which require claims for an airline's biofuel use for flights from a specific airport not to exceed the fuel use for the airline's flights subject to the ETS from that airport.

In a global scheme these restrictions are less relevant and the accounting system could thus be much simpler. However, domestic flights are not included in the ICAO scheme and it is also envisaged to exempt

flight connections with some countries having very little aviation activity, such as least developed countries. Nevertheless, it would not be desirable to prevent recognition of biofuel use on flights to and from these countries because in many of them biofuel production is seen as a new source of livelihood and a chance to reduce dependence from oil imports.

While a high degree of freedom for the use of biofuels is desirable once the fuel is ready for use and has been introduced into the aviation logistic system, a closer monitoring of the production of biofuels is necessary to ensure the sustainability properties of the commercial product. A mass-balance chain of custody following the amount of feedstock and intermediary products certified for sustainability ensures that the amount of fuel for which emissions reduction claims are made really originate from sustainable production.

2016 will be an important year with the ICAO General Assembly in October. Viable options for the harmonisation of sustainability standards and alternative jet fuel accounting rules will continue to be developed in preparation for the proposed implementation of the MBM in 2020.

3. <http://www.emissions-euets.com/httpemissions-euetscomindexphoptioncomcontentaviewarticleaid232>

3. Sustainability

3

3.1 Chapter summary

As highlighted in Chapter 2, different sustainability standards are in use for aviation alternative fuel, both regulatory and voluntary. A selection of some prominent standards are referenced in the previous chapter, including some of the differences between these standards, and the merit for harmonization or a pathway to mutual recognition.

One voluntary standard which is widely used by the aviation industry is the Roundtable on Sustainable Biomaterials (RSB). The RSB has certified the first biojet fuel supplier (SkyNRG) and several aviation biofuel initiatives have recommended using RSB standards for their biofuel supplies. A list of RSB participating operators can be found at the following link: <http://rsb.org/certification/participating-operators/>

This chapter highlights some of the activities of RSB and IATA gratefully acknowledges Rolf Hogan at RSB for coordinating the contribution.

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 is 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.

While there are a variety of regulatory and voluntary sustainability standards that are applicable to aviation biofuels, this chapter reports on some recent developments from RSB.

3.3 Roundtable on Sustainable Biomaterials (RSB)

2015 has been an action-packed year for RSB. RSB's active engagement with industry leaders has led to a growth in certification and membership, and new advisory services have been developed to support implementation of the RSB standard by industry. Specific products have been developed for the investment sector which RSB hopes will help to de-risk investments and save costs by integrating sustainability considerations into projects at the design stage. We are already seeing strong interest in these services. RSB's commitment to linking smallholder farmers to markets has also advanced through the first certifications in South Africa and Southeast Asia. And the RSB standard continues to be improved and streamlined most notably with the adoption of a module for low indirect land use change (iLUC) risk biofuels by the RSB General Assembly.



RSB Board Members, June 2015, Photo Credit: RSB

The following sections describe some notable developments that have taken place over the past year.

3.3.1 Aviation Industry Support

Throughout 2015, the aviation sector continued to support and endorse RSB as the most credible global standard for ensuring the sustainable production of biofuels and biomaterials. This was evidenced through several new RSB members from the aviation sector such as South African Airways (SAA) and Sunchem Holdings, as well as multiple reports and articles featuring RSB by Etihad Airways, Virgin Atlantic, Boeing, United Airlines, NRDC (Natural Resources Defense Council), and WWF (World Wide Fund for Nature).

“Membership of the RSB not only serves as recognition of SAA’s African biofuels programme, but provides us with a further networking platform to engage with NGOs and leaders in the biomaterials field.”

– Nico Bezuidenhout
SAA’s Acting CEO

In his new book *Will Sustainability Fly?*, Walter Palmer says:

“Its (RSB’s) credibility and usefulness derive from its commitment to strong, hard, measurable standards, along with its remarkable support by many players from different sectors, including agriculture, environmental and social advocacy, industry (manufacturing, transportation, banking), as well as intergovernmental and non-governmental groups...the RSB seems to be the most successful effort at certifying fuels and other biomaterials in a comprehensive and valid way.”

3.3.2 New Services for Investors

RSB has developed services to support investors in assessing and mitigating risks before making decisions for investments in bio-based projects. The new services will firstly help project developers to integrate RSB principles at the project design stage and secondly help investors to ensure sustainability has been effectively integrated into the project when they carry out their due diligence. Discussions on the new products were initiated developed with partners at a meeting held in KLM offices in March 2015 and were endorsed by the RSB Board of Directors in October 2015. The RSB is currently consulting with the investment sector to understand the demand. The new services will be piloted in 2016.

3.3.3 New Training and Advisory Services

RSB has started providing advisory and training services to help companies implement the systems necessary to achieve RSB certification in a way that aligns with their existing business practices. Getting RSB help as companies are implementing new procedures ensures that compliance with the RSB standard and the third party audit is seamless and straight forward. Several companies in the aviation sector have already shown interest in these services and requested proposals from RSB.

One of the new services includes a face-to-face training course to prepare staff and ensure they understand the main aspects of the RSB Standard and the new company procedures needed to achieve certification. The training and advice is provided by RSB staff, who have extensive practical experience of auditing and process operation, and in-depth knowledge of the RSB Standard as well as the biofuels road and air transport market in Europe and the U.S. They can share valuable insights on the topics currently being considered by regulators and how they expect regulation and incentives to develop.

3.3.4 New Certifications around the World

RSB continues to expand certifications covering a variety of feedstocks and operator types around the world. Certifications for several additional operators in China, Brazil, Tunisia, Paraguay, and the USA are

nearing completion, including some related to aviation. Certification highlights for 2015 include:

- **Advanced Biochemicals (Thailand) Co., Ltd (ABT)** – Solvay subsidiary ABT was the first biochemical producer in Asia to obtain RSB certification. They received certification for the production of Epicerol®, a bio-based building block for renewable chemicals and resins.
- **Biomass Supplies** – The first smallholder project in Southeast Asia to earn RSB certification, their innovative use of gliricidia trees for biomass is helping over 30,000 small farmers in Sri Lanka to plant more trees and improve their livelihoods.
- **Nidera BV** – A large trader for biodiesel from wastes and residues earned RSB Certification for multiple sites across Europe.
- **GoodNRG B.V.** – This trader based in the Netherlands earned RSB certification for their biofuels and bioliquids in the marine, heavy trucking, and rail industries.
- **Greenergy Fuels Ltd.** – One of Europe's leading manufacturers of waste based biodiesel earned RSB certification for the production of biodiesel from used cooking oil at several sites in the UK.
- **Sunchem Biofuel Development South Africa** – RSB's first smallholder project in South Africa was certified for the Solaris seed tobacco produced for biojet fuel. This collaboration with SkyNRG, South African Airways (SAA) and Sunchem is helping improve local communities in South Africa while providing the aviation industry with sustainable biojet fuel.



Local farmers out on the field with the RSB auditor, Photo Credit: Biomass Group

3.3.5 RSB and the UN Sustainable Energy for All Initiative (SE4All)

RSB and the UN Food and Agricultural Organisation (FAO) are chairing the Sustainable Bioenergy Group (SBG) of SE4All. The coalition aims to speed up the development and deployment of sustainable bioenergy in order to contribute to meeting the SE4ALL goals of doubling the global use of renewable energy and ensuring universal energy access by 2030. Supported by Novozymes and the Inter-American Development Bank (IDB) SBG members include Bloomberg New Energy Finance, KLM, and the United Nations Foundation.

"RSB sees SE4All as a key framework to promote sustainable bioenergy at scale and believes that it will lead to the advancement of sustainable production on the ground supporting rural development, workers' rights, biodiversity protection and reduction of greenhouse gas emissions in line with international best practice outlined in the RSB standards," said RSB Chair Barbara Bramble at the SBG launch in New York in May 2015. "We are really delighted to see the initiative kick-off and look forward to working with our members and partners to make it a success."

3.3.6 RSB First Certification System to Develop Low iLUC Risk Standard

In June 2015, RSB's Assembly of Delegates approved the new "Low iLUC Risk Biomass Criteria and Compliance Indicators" also known as the "iLUC Standard", becoming the first sustainability certification standard to do so. This Standard helps producers demonstrate that biomass was produced with low indirect land use change (iLUC) and therefore minimal impact on food production or biodiversity. RSB is also currently undergoing revisions and updates to its Principles & Criteria based on feedback from RSB members and public consultation in 2015. An updated version is expected in 2016.

3.3.7 Smallholders

With the support of the Boeing Corporate Citizenship Program and the Swiss government, RSB's Smallholder Program entered its second year with progress on certification in Brazil, South Africa and Sri Lanka. The program seeks to improve the livelihoods

of smallholder farmers by linking them to markets and promoting sustainable practices based on the [RSB Smallholder Standard](#).

In 2015, **Sunchem Biofuel Development South Africa** earned RSB certification for the production of the energy rich tobacco crop “Solaris” in South Africa. The initiative ‘Project Solaris’ involved several partners including RSB-members South African Airways and SkyNRG as well as RSB support for application of the standard. The project has brought economic and rural development to the Limpopo province as well as a new regional bio jet fuel supply chain that is now RSB certified for environmental and social sustainability.

Also in 2015, [Biomass Supplies](#) (Pvt) Ltd based in Sri Lanka earned RSB certification for biomass produced from branches pruned from live fences of Gliricidia trees. The certification covers Biomass Supplies’ work with 30,000 small farmers who have planted 60 million new trees. Biomass Supplies is the first smallholder project to become RSB certified in Asia. Sustainability, traceability, and accreditation will enable Biomass Supplies to command fair prices which in turn will provide local farmers with a better income.

Effective policy must play a growing role in advancing the deployment of sustainable alternative jet fuel.

The following policy instruments need to be applied to result in action. There is not one ‘silver bullet’ perfect policy. Different economies, geographies and government priorities will dictate a different application of instruments. Often combining policy initiatives will achieve more than a single policy application. Additionally, it is vitally important for policy makers

to understand how policy tools impact project cost-benefit scenarios.

The industry believes some of the most important policy requirements to enable sustainable alternative fuel production and deployment to advance are:

1. At least a level playing field for alternative fuel use between the air and road sector – currently, policy measures in a number of regions are more heavily focused on road use where personal vehicles should be looking towards other energy sources such as electricity.
2. Research aimed to lower feedstock costs and new production processes – aviation is keen to access as many sources of alternative fuel as possible, as long as sustainability criteria are maintained.
3. De-risk public and private investment in production – production grants have been effective and guaranteeing the building of production facilities can help start putting bioenergy on a similar footing as fossil fuel
4. Incentivise airlines to use SAF from an early stage to help boost the market and catalyse investment
5. Support robust sustainability criteria and international efforts to harmonise these – a global industry needs global standards and aviation is focused on ensuring sustainability of supply as much as cost.
6. Foster local opportunities (localised scoping studies and roadmaps are effective) – there may be local sustainable alternative energy industries that could be fostered, providing economic benefits and bringing the green economy to parts of the world not currently included.

4. National and International Biojet programs

4

4.1 Summary

This chapter provides a description of some recent biofuel developments from industry stakeholders. Some particular highlights include:

- The Commercial Aviation Alternative Fuels Initiative (CAAFI) is engaged in various activities to enable and facilitate the near term development and commercialization of such fuels
- aireg – Aviation Initiative for Renewable Energy in Germany e.V. has stepped up its efforts to prepare a continuous supply of alternative jet fuel in Germany. Its member organizations have initiated a great number of innovative projects, which in combination contribute to achieve aireg's goal of substituting 10 percent of the German jet fuel demand with sustainable alternatives by 2025.
- The ITAKA project is contributing to support the development of aviation biofuels in an economically, socially, and environmentally sustainable manner, improving the readiness of existing technology and infrastructures.
- Canada's Biojet Supply Chain Initiative (CBSCI) is aiming to help enable carbon neutral growth in the Canadian aviation sector through the downstream integration of biojet fuel produced from certified sustainable, domestically produced oleochemical feedstocks in a comingled airport fuel supply system
- A perspective on Solar-Jet Fuel

IATA gratefully acknowledges the contribution to this Chapter from: Steve Csonka (CAAFI), Lukas Rohleder (aireg), Inmaculada Gomez (ITAKA), Fred Ghalata (GARDN), Arne Roth (Bauhaus Luftfahrt)

4.2 National and international alternative jet fuel progress – The CAAFI perspective

The Commercial Aviation Alternative Fuels Initiative (CAAFI®) is a North America-centric coalition of aviation stakeholders who are interested in bringing commercially-viable, sustainable alternative jet fuels (SAJF) to the marketplace to help meet the sustainability goals of the jet-powered aviation community. CAAFI is sponsored by the US Federal Aviation Administration (FAA), Airlines for America (A4A), Airports Council International – North America (ACI-NA), and the Aerospace Industries Association (AIA). CAAFI is also supported by over 800 members and 350 organizations from around the globe. Efforts are accomplished via the support of the sponsors and members who engage in four work teams, as well as several Public Private Partnership activities, that leverage the interests of government agencies and other aviation stakeholders.

CAAFI® is engaged in various activities to enable and facilitate the near term development and commercialization of such fuels. It serves primary roles of thought leadership, project execution, collaboration, instigation, and communication. It also serves as a coordinator/clearinghouse, facilitating the exchange of information about private-sector and governmental initiatives supporting the development and commercialization of “drop-in” alternative aviation fuels. While CAAFI's efforts are focused on opportunities in the U.S., CAAFI also recognizes the need to foster similar efforts around the globe, and as such, works with similar organizations and other interested parties in many countries.

4.2.1 Current U.S. Federal efforts to facilitate SAJF development, testing, and deployment

Researchers, government, and industry leaders are collaborating to develop, assess, and deploy SAJF. Activities of the U.S. Government with CAAFI affiliation include the following:

- The FAA has taken a number of proactive steps to identify and fund SAJF activities. Along with funding CAAFI, other major initiatives include:
 - The Aviation Sustainability Center (ASCENT), a university research consortium/center of excellence for Alternative Jet Fuel and the Environment⁴. The ASCENT teams are currently working multiple projects dealing with supply chain analytics and combustion science;
 - Continuous Low-Energy, Emissions, and Noise (CLEEN), which, in addition to supporting the development of technologies to improve efficiency, and reduce noise and emissions, has also focused on testing of SAJF to support ASTM qualification, but also to quantify the benefits of using such fuels;
 - Farm to Fly 2.0, a joint effort between USDA, DOE, FAA and industry to develop supply chains to support the goal of one billion gallons of SAJF in use in the United States by 2018.
- The U.S. Departments of Agriculture is focused on feedstock development and commercialization using many departments/mechanisms including major programs and services in the area of Assisting Rural Communities, Conservation, Education and Research, Food and Nutrition, and Marketing and Trade. Specific efforts include the work of several ARS Research Centers, seven NIFA/AFRI CAPS (coordinated agricultural projects), several Rural Development programs, and leadership in the Farm-to-Fly 2.0 program, amongst others.
- The U.S. Department of Energy is focused on technology development, leveraging the interests and resources of the Office of Energy Efficiency and Renewable Energy, and its BioEnergy Technologies Office (BETO – <http://www.energy.gov/eere/bioenergy/bioenergy-technologies-office>) via a broad range of research, development, demonstration and deployment initiatives. DOE,

along with USDA, also spearheads the efforts of the Biomass Research and Development Board which has funded R&D, and demonstration and deployment efforts through the ongoing BRDI initiative.

- The U.S. Department of Defense, through significant work of the USAF and USN, has spearheaded testing and qualification efforts, and is assisting with commercialization through Farm-to-Fleet efforts (fuel acquisition), as well as Defense Production Act (DPA) efforts to lower capital expenses for several production facilities.
- Additionally, the U.S. Departments of Commerce, EPA, NASA, and National Science Foundation, have partnered to coordinate and focus federal research and policy support efforts on SAJF.

4.2.2 Progress

Fuel Specification Approvals. CAAFI® has developed guidance on getting alternative jet fuels approved by ASTM, and established a process to coordinate progression of reviews. As of November 2015, three drop-in alternative jet fuels have already been approved in the ASTM D7566 annexes for commercial use, while an additional annex has been successfully balloted, but not yet published. The initial ASTM D02.J Isobutanol Alcohol-to-Jet (ATJ) Research Report was released for ballot on October 23, 2015 and is expected to advance to final committee level ballot in 1Q 2016. Seven additional processes are currently being evaluated by ASTM Task Forces with the goal of achieving multiple ASTM D7566 qualifications in the next several years. The developers of several additional processes, currently at low levels of Fuel Readiness Level, are expected to engage with ASTM in the coming years.

Fuel & Feedstock Readiness Tools. CAAFI® has developed a collection of tools that facilitate assessment and advancement of fuel and feedstock readiness with respect to ASTM approval, R&D and deployment activities, environmental sustainability, and commercialization.

Stakeholder coordination and communication. CAAFI® enhances communication among government agencies, aviation sector trade associations, industry, fuel producers, feedstock producers, academic researchers, and non-governmental organizations via the CAAFI® Biennial General Meeting and team meetings, Global Exchange with other public-private partnerships

4. <https://ascent.aero/>

around the globe, webinars, conference presentations, and other venues.

Strategic thought leadership. CAAFI® participates domestically with interagency working groups and strategic initiatives (e.g., Federal Alternative Jet Fuel Strategy, Biomass Research and Development Board's Technical Advisory Committee, Billion Ton Bioeconomy), collaborative forums, alternative jet fuel research consortia (e.g., ASCENT), to help drive collective efforts toward commercialization.

State Initiatives. CAAFI® works closely with stakeholders to help develop state-level deployment initiatives for alternative jet fuels. A state-level initiative is focused on facilitating the connection of representatives from all parts of the supply chain who can work together to develop, evaluate, and execute a specific deployment project. CAAFI® has facilitated formation of supply chains for alternative jet fuel deployment through the State Initiatives, now underway in 8 states within the U.S.

International Collaborations. CAAFI® initiated an ongoing “global exchange” of ideas to facilitate complementary work programs and help aviation present a united framework to facilitate development and deployment of SAJF. The various organizations working to advance alternative jet fuels understand that fuel production and commercialization will entail an effort requiring support from various stakeholders and entities. CAAFI® also participates in key international events such as the Alternative Fuel Symposium held in November 2015 by the International Air Transport Association (IATA).

Currently, task groups within ICAO's Committee for Aviation Environmental Protection are defining a global market-based measure that will delineate the approach for emissions calculations, credits for alternative fuels, and qualifying offsets. Within the United States, an interagency working group including Department of Defense, FAA, DOE, EPA and other agencies and researchers defined a life cycle GHG inventory approach for alternative jet fuels, and analytical models of jet-fuel specific pathways are available from the Argonne National Laboratory's Greenhouse gases, Regulated Emissions and Energy Use in Transportation (GREET) model.

4.2.3 The market for alternative jet fuels

In the U.S., CAAFI® expects the three DPA awardees to start producing alternative jet fuel in 2016/2017. Unlike other sectoral off-takers, airlines have expressed a willingness to enter into longer-term purchase agreements (e.g., 5–10 years, which might prove beneficial to producers obtaining commercial financing), and some have already done so (see Table 1–1).

The International Air Transport Association (IATA) has developed a model alternative jet fuel purchase agreement that provides prospective fuel sellers with an understanding of what is required in order to successfully sell alternative jet fuel.⁵ CAAFI® has provided additional guidance for potential alternative fuel producers who are interested in presenting offtake opportunities to prospective SAJF producers.⁶

Table 3.1. Selected announced SAJF purchase agreements as of November 2015.

Aviation purchaser	SAJF producer	Amount
United	AltAir Biofuels	5 M gallons per year (GPY) for 3 years from 2015
Alaska Airlines	Hawaii BioEnergy	Undefined quantity from 2018
Cathay Pacific	Fulcrum Bioenergy	375 M gallons over 10 years
Southwest	Red Rock Biofuels	3 M GPY for 7 years from 2017
FedEx	Red Rock Biofuels	3 M GPY for 7 years from 2017
GE	D'Arcinoff Group	0.5 M GPY
Gulfstream	World Fuel Services	3 year supply agreement
United	Fulcrum Bioenergy	90 – 180 M GPY over 10 years
World Fuel Services	AltAir Biofuels	n/a

5. See <http://www.iata.org/policy/Documents/afsm-a-oct2013-%20f1-complete%20pdf.pdf>

6. See http://www.caafi.org/files/CAAFI_Business_Team_Guidance_Paper_060413.pdf

4.2.4 Conclusion

CAAFI® is confident that SAJF derived from several families of feedstocks will be commercially available in the next one to five years. CAAFI® is working with other stakeholders to enable various industry goals, including FAA's articulated goal of having one billion gallons of alternative jet fuel in use in the US by 2018, as well as the commitment of the industry to achieve net carbon neutral growth in international aviation from 2020 onward, etc. CAAFI continues to develop concepts that can remove barriers to more timely and less costly development and ASTM qualification, as well as those leading to supplier commercialization.

CAAFI will continue to work with U.S. Federal agencies to encourage the development of sustainable supply chains for drop-in SAJF. Airlines have demonstrated their interest through offtake agreements with the pioneering companies that plan to produce SAJF in commercial quantities. The aviation sector anticipates significant growth in SAJF production in the near term, and CAAFI intends to continue facilitating market development through its breadth of activities.

CAAFI acknowledges and welcomes the significant contributions, collectively and individually, of many other aviation industry partners who share the interests of the aviation enterprise to decouple GHG growth from market-driven increases in traffic/operations. In many cases, CAAFI has no direct involvement in the successes of other individual efforts, but as a clearing-house for communicating progresses and challenges, CAAFI will often highlight such efforts for the benefit of the entire industry.

4.3 German success stories towards a steady bio jet supply chain

With a strong and growing support of industry and research organizations aireg – Aviation Initiative for Renewable Energy in Germany e.V. has stepped up its efforts to prepare a continuous supply of alternative jet fuel in Germany. Its member organizations have initiated a great number of innovative projects, which in combination contribute to achieve aireg's goal of substituting 10 percent of the German jet fuel demand with sustainable alternatives by 2025.

4.3.1 Feedstocks

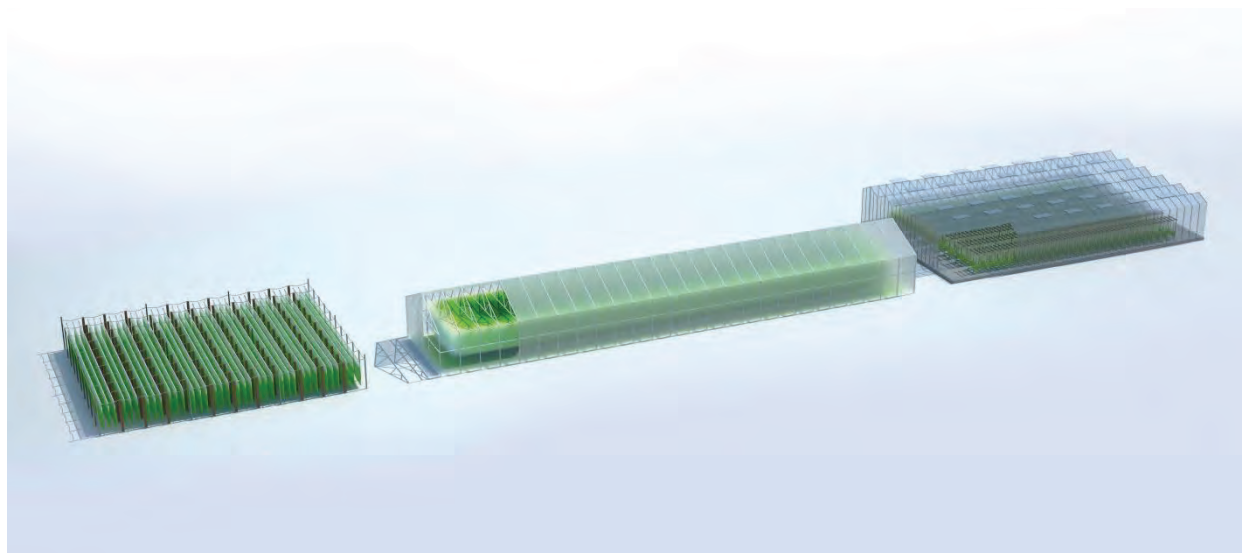
What contribution could sustainably produced biomass make as an energy source to the realization of a renewably fueled transport sector in general and the aviation sector in particular under ideal economic, agricultural and political conditions? This as yet insufficiently answered question was addressed in the **Raw Material Capacities** project funded by the German Federal Ministry of Transport and Digital Infrastructure (BMVI) and conducted by Bauhaus Luftfahrt and INOCAS. The research was carried out on the basis of high resolution spatial data (a cell size of up to 0.46 km²) and under the consideration of strict sustainability principles (climate change mitigation, food security, protection of biodiversity, protection against deforestation, soil degradation/erosion, depletion of fresh water resources and land use change). Results will soon be published by BMVI.

To improve the economics of bio-SPK, JatroSolutions has established a **global jatropha breeding program** for high yielding hybrid cultivars. In addition to the excellent vegetable oil, these new jatropha cultivars will permit a high valorization of by-products. In parallel, mechanized harvest systems are being developed. In a next step JatroSolutions is going to implement commercial scale projects to proof that all requirements (price, quality, availability and sustainability) can be met. (www.jatrosolutions.com)



One of JatroSolutions Jatropha test farms in Madagascar

Algae instead of petroleum – that is one of the ideas for advanced biofuels for aviation. In the joint research project **AUFWIND**, scientists of Forschungszentrum-Jülich investigate, together with 12 partners from academia and industry, how micro-algae can be used as a source for jet fuel. Key questions are the commercial and ecological bottlenecks of the process.



Algae Science Center – AUFWIND project site at Forschungszentrum Jülich; technologies from left to right: phytolutions, IGV and NovaGreen

1,500 m² (0.37 acres) of algae photobioreactors were built in Jülich and the conversion of algae to kerosene investigated by the consortium. It is the first step from laboratory-scale research towards a commercial production of algae-fuel in Germany. The Federal Ministry of Food and Agriculture government funds the approach with more than 6 million euros.

In the project **Advanced Biomass Value**, funded by the German Federal Ministry of Education and Research BMBF, microalgae are used as a platform for the production of various value-added products (bio-refinery concept). In a first step, highly productive microalgae species are cultivated and harvested. The oil within the algae cells is extracted with supercritical CO₂, a non-toxic solvent, and further processed into bio-lubricants and high value additives. In a second step, the oil-free algae biomass is enzymatically upgraded into a sugar containing growth medium. This sugar in the medium serves as feedstock for oil yeasts that are utilized for the subsequent production of renewable aviation fuels. The consortium, with the aireg member organizations TU Munich, Bauhaus Luftfahrt and Airbus and other partners, will run until 2017.

Novel approaches for production and processing of microalgae cultivation are examined in the Bavarian research project **Algenflugkraft** (AFK). For example, inclined reactors are studied in comparison to “traditional” open raceway ponds and standard cell disruption and extraction techniques are replaced by

an innovative procedure based on the utilization of ionic liquids. However, the most notable aspect of the AFK-project is the **Algentechnikum** (located at the Airbus facility in Ottobrunn), a newly erected research facility that allows the study of algae production for a wide variety of climatic conditions. For this purpose the Algentechnikum was equipped with a unique LED irradiation system capable of simulating natural sunlight and a sophisticated temperature regulation. AFK, which is cooperation of TU Munich, Airbus, Bauhaus Luftfahrt, Clariant and Conys, received funding from the Bavarian Ministry of Economic Affairs and Media, Energy and Technology.



The Algentechnikum opened in October 2015 at the Ludwig-Bölkow-Campus in Ottobrunn near Munich

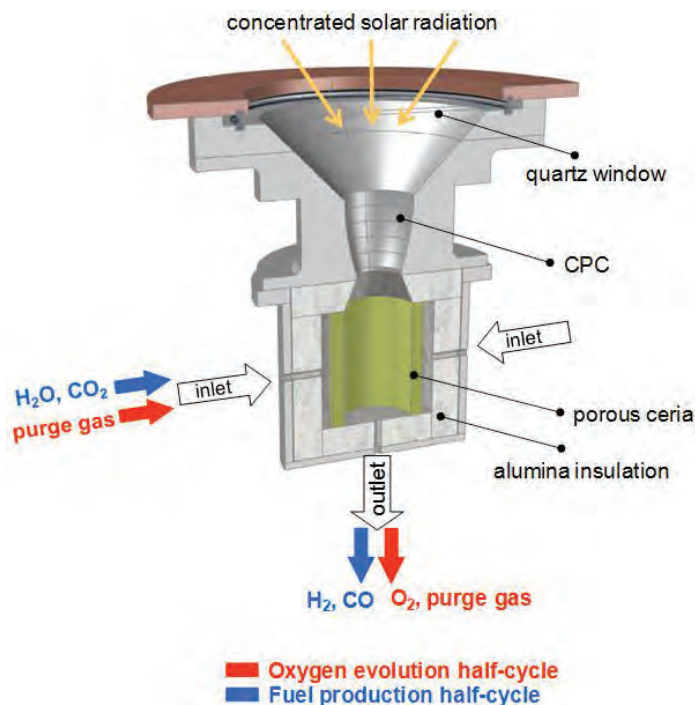
Understanding and optimizing the oil productivity of algae is the focus of **OptimAL – optimizing algae for fuel**. Research topics are algae metabolism, adaption towards challenging conditions i.e. light, temperature and nutrients stress, as well as basic understanding of green algae as a novel crop. This fundamental research is conducted by Forschungszentrum Jülich with support of € 1.3 million from the German Federal Ministry of Education and Research (BMBF) with.

4.3.2 Fuel production

The EU-funded project **SOLAR-JET** has succeeded to synthesize the world's first "solar" kerosene from water, CO₂ and solar energy by coupling a two-step solar thermochemical cycle with a Fischer-Tropsch synthesis. The experimental realization utilized a unique solar simulator facility at ETH Zurich and research scale gas-to-liquid conversion at Shell laboratories in Amsterdam, while Bauhaus Luftfahrt acted as coordinating partner and DLR supported the project with simulations. In the long-term perspective the SOLAR-JET process will provide a secure, sustainable and scalable source of renewable fuels, which would protect bio diversity and avoid food vs. fuel conflicts. The next step along the technology development roadmap will cover efficiency improvement, scale-up, and field validation. (www.solar-jet.aero)

Global Bioenergies is currently building a **demonstration plant** in the Fraunhofer CBP building in Leuna, dedicated to the production of high purity isobutene from renewable resources. A 5,000 litre fermenter should be delivered in Q1 2016 and the purification unit in Q2 2016. Final assembly on site is expected by July 2016. The plant is designed for an isobutene production capacity of up to 100 tons per year. Isobutene, a gaseous hydrocarbon, can be used for the fabrication of plastics, elastomers as well as drop-in fuels for gasoline (isooctane) and jetfuel (isododecane). Global Bioenergies was awarded a € 5.7 million grant for the demo plant from the German Federal Ministry of Education and Research (BMBF) within the "BioEconomy Cluster" framework. (www.global-bioenergies.com)

A feasibility study has investigated the potential for **bio-kerosene from bio-methane** in Lower Saxony via the Gas-to-Liquid (GtL) pathway. For this purpose a flow-sheet simulation of the GtL-process was carried out. Different scenarios including synergies with local industries were evaluated regarding technical, economical and ecologic parameters. It was found that possible prices range from 1213 to 3374 €/t of kerosene, while GHG-emission reduction ranges between 40 and 61% (compared to fossil fuel), depending on scenario and timeframe. There is a potential to cover



Schematic of the solar reactor configuration for the 2-step solar-driven thermochemical production of fuels (www.solar-jet.aero)

1 to 12% of Lower Saxony's annual demand with local bio-kerosene, as the study showed. (www.tuhh.de/iue)

Fraunhofer UMSICHT has studied the **catalytic condensation of alcohols** and the cross-condensation of alcohols and ketones, like acetone, in the gas-phase as a new pathway towards biofuels. Suited feedstock can be sourced from fermentation of sugar containing residues, e.g. through ABE-fermentation. A water tolerant, continuous process employing a commercial catalyst was developed and is operated on a scale of 10 liter/week. The process delivers a mixture of branched molecules consisting of alcohols, ketones and some aldehydes (intermediates) next to water. A tailor-made carbon chain distribution and branching can be achieved. A hydrotreatment step transforms the intermediates to jetfuel and diesel. (www.umsicht.fraunhofer.de)

Hamburg University of Technology has conducted a **study on prospects of different AtJ pathways** addressing state of the art, feedstock potential, conversion processes and fuel properties. Several technologies for converting alcohols into synthetic kerosene have been assessed, most of them relying on methanol, ethanol or butanol as platform molecule. These alcohols may be derived from a variety of feedstocks, including sugary, starchy and lignocellulosic biomass employing thermo-chemical and bio-chemical (fermentation) processes. The final evaluation was based on conversion efficiencies and production costs. Based on current price for conventional jet fuel, neither AtJ fuel was competitive on an economic basis. In all scenarios product costs were highly dependent on the costs of the biomass feedstock.

The aim of the project **InnoTreib** is the development of methods for the design of optimized and innovative fuels with an application horizon of 2030+. Therefore both sides, the fuel production and the fuel use in aviation turbines are interlinked in an optimization environment. Thus the fuels can be optimized with regards to individual parameters by using modelling methods for the fuel production (process modelling) as well as the fuel use (CFD simulations with detailed reaction mechanisms). At the end of the project stands a tool that gives the user an easy optimization approach specific to the respective needs. Funding was provided by the German Federal Ministry of Economics and Energy to the project partners DLR, University of Stuttgart and Hamburg University of Technology.

4.3.3 Policy

aireg's policy initiatives have focused largely on the need for feedstock and biorefining capacity at industrial scale. As can be seen from the projects above, several Federal Ministries are significantly contributing to these efforts. From a conceptual perspective, the Mobility and Fuels Strategy (MKS) of the German Federal Government, implemented by the Federal Ministry of Transport (BMVI), remains the single most important policy tool to date.

4.4 The Initiative Towards sustAinable Kerosene for Aviation

4.4.1 Background

The Initiative Towards sustAinable Kerosene for Aviation (ITAKA) is a collaborative project framed in the implementation of Global, National and European Union policies, and specifically aims to contribute to the fulfilment of some of the short-term (2015) EU Flight Path objectives.

The ITAKA project is contributing to support the development of aviation biofuels in an economically, socially, and environmentally sustainable manner, improving the readiness of existing technology and infrastructures.

ITAKA is a first of its kind collaborative project in the EU, which has started the development of a full value-chain in Europe to produce sustainable drop-in Hydroprocessed Esters and Fatty Acids (HEFA) at industrial scale. The value chain will be fully demonstrated by testing the use of the biojet fuel produced in existing logistic systems and in normal flight operations in the EU.

4.4.2 From feedstock to flight: the ITAKA full chain assessment

ITAKA targets camelina oil as the best possible sustainable feedstock that can be produced in a timely fashion at the required quantities within Europe. In order to achieve this target, 3 camelina large scale plantations in Spain and several smaller plantations in Romania have been grown and harvested, providing further inputs about optimal cultivation protocols and

yields. The plantations served not only for providing the oil to the value chain, but also to optimize the camelina growing protocols and to select new camelina varieties with increased oil content adapted to the European soil and climate conditions.



Camelina crop scheme and co-products.

In parallel, several R&D trials have been conducted in Spain and in Romania to improve the productivity and sustainability of camelina oil as a suitable and efficient feedstock for the production of biojet fuel.



Plants of camelina germinating.

Used cooking oil (UCO) has also been considered as a complementary feedstock for sustainable biojet fuel production within the project. New techniques for the pre-processing of the UCO have been developed, delivering in depth studies for the use of a pyrolysis unit to enhance the properties of the oil.

4.4.2.1 Refining the oil to jetA1

Using an **existing plant** (Neste, Porvoo, Finland), the target is to enable the production of biojet at an industrial scale.

During the first half of the project, minor improvements have been made at the refining facilities in order to be better adapted to the biojet requirements. The methodology for in house fuel quality analyses was also developed to enable the full-scale quality certification analyses of biojet.

4.4.2.2 Leverage the logistics

ITAKA addresses all **downstream logistics** (blending, transport, storage and airport supply operations) **at large scale**, both through a dedicated and a non-dedicated system.

The already existing fuel infrastructure is being tested (refinery to fuel farm, fuel farm and fuel farm to delivery into aircraft), including the administrative barriers such as different ownership of operators, lack of proper protocols, lack of regulations framework, etc.

In addition, parallel issues such as the storage of the biofuels, blending and delivery procedures are being managed within the project, providing valuable information about the optimal handling of biojet in regular operations.

A blending accountability to be **tracked** is being developed, based on **chain of custody** documentation and mass-balance basis. This is especially relevant for the accountability in the EU of the use of biojet fuel towards the **EU Emissions Trading System**.

4.4.2.3 Engine and fuel systems testing

ITAKA targets to **allow evaluation of the impacts on aircraft operations** in typical flights in Europe.

Fuel systems testing is being carried out and relevant datasets shall be collected for the final assessment. The achievements up to date are:

- 18 flights AMS-AUA-BON, long haul flights (10 h), showing no detrimental effects on operation or performance. The data obtained have been used to complement the monitoring & modelling systems at OEMs systems for the use of biojet fuel.
- APU tests for pollutant emissions have been carried out, showing a reduction in fuel flow (due to the different energy density), reduction in the SAE smoke number and possible reduction in particulate matter (PMs). No relevant changes were observed in NO_x or UHC values.



Next planned steps for fuel systems testing:

- **Regional flights:** About 80 flights on Embraer E190 regional aircrafts – (KLM Cityhopper) are planned to **complement/contrast** the data on **long haul flights** with the A330-200 (2014). The base for the analysis is an **Engine & Fuel System** “back to back” performance analysis compared to fossil jet.
- **Airport:** ITAKA works to develop the **first** of its kind airport trial in Europe in order to **demonstrate** the use of biofuels in the co-mingled system as the best valid future scheme. With this demonstration we will help **remove any barrier** associated with large scale use of biojet fuel and **demonstrate** there is not any **influence** of the certified biojet fuel on **infrastructure** (e.g. gaskets) and **fuel operations** (e.g. interface detection). As consequence ITAKA will **demonstrate** that biojet fuel can be accepted in existing infrastructure without further testing. In addition, ITAKA will propose accountability/balance methodology compatible with the existing standards and regulations.

4.4.2.4 Make it Sustainable!

Sustainability, competitiveness and technology assessments have been initiated, studying economic, social and regulatory implications of large-scale use. ITAKA will ensure GHG savings reached by means of several lifecycle assessments.

The initial results following the RSB EU RED standard point to GHG emissions savings over 60% in the camelina to biojet pathway. This is from the camelina plantations located in Spain which are the first camelina plantations to be RSB certified. Additionally, feedstock and fuel produced in the ITAKA framework, is also compliant with the RSF2 (US regulation) and has received a positive endorsement from SkyNRG’s sustainability board, that include principles that differ

slightly from those on the EU regulation (EU RED). As result, ITAKA is also providing results on assessment on the use of different sustainability standards along the value chain.

Camelina oil is produced with a **low risk of indirect land use change** (ILUC), being the camelina grown on otherwise fallow land (underused land), on rotation with cereal in dry areas in Spain. Using this procedure, growing camelina doesn’t demand additional land or substitution of crops.

Interesting results have been obtained from the potential to grow camelina in **polluted lands** while the oil and camelina meal could be still used on most cases. This could help also to make a more efficient use of the available resources.

The socio-economic effects of the biofuel production are also being addressed, and the first results show positive potential effects of the cultivation of camelina in Europe, particularly having high potential in Eastern Europe (referred from Romania).

The generated knowledge will aim to identify and address barriers to innovation and commercial deployment.

Beyond these technological and research objectives, ITAKA is also willing to contribute to the achievement of a further EU objective: the need to coordinate efforts and complementarities among European initiatives on sustainable aviation fuels, as highlighted during the Flight Path definition and identified in SWAFEA 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 and to make a first significant step in the establishment of such a European network. Currently ITAKA is connected and collaborating with the main biojet fuel initiatives in Europe and worldwide.

4.4.3 About ITAKA

The ITAKA Consortium is composed by companies from 9 countries and coordinated by SENASA, and represents the actors involved in the full production and value chain: Airbus Group (FRA, UK), Biotechgen (RO), Camelina Company España (ES), CLH (ES), Embraer (BR), EPFL (CH), Manchester Metropolitan University (UK), Neste (FI), RE-CORD (IT), SkyNRG (NL).

More information on the results and details of the project can be found at www.itaka-project.eu.

4.5 Canada's Biojet Supply Chain Initiative: Enabling 2020 Carbon Neutral Growth

4.5.1 Introduction and status

The purpose of Canada's Biojet Supply Chain Initiative (CBSCI) is to help enable carbon neutral growth in the Canadian aviation sector through the downstream integration of biojet fuel produced from certified sustainable, domestically produced oleochemical feedstocks in a comingled airport fuel supply system. The Initiative will utilize the proposed IATA and Ecofys accounting methods for biojet tracking, as well as the meta-standard approach for biojet sustainability. Incorporating these potential biojet accounting methodologies and testing their functionality, practicality, and relative administrative burden, will be a key contribution of CBSCI.

The biojet fuel will be produced using the Hydroprocessed Esters and Fatty Acids (HEFA) process and will be blended with the domestic jet fuel supply pursuant to ASTM specifications.

In November 2015, the CBSCI initiative is completing the necessary agreements to enable implementation in the first quarter of 2016. Select operational details, such as airport location of downstream blending, HEFA biojet production location, and feedstock composition, will be confirmed following completion of agreements.

This Initiative involves 14 stakeholder organizations, coordinated through BioFuelNet Canada's Aviation Task Force, with primary funding from the Green Aviation Research and Development Network (GARDN), a non-profit organization funded by the Business-Led Network of Centres of Excellence of the Government of Canada and the Canadian aerospace industry. Waterfall Group of Vancouver, Canada is the project lead, and Air Canada, with headquarters in Montreal, is providing significant support to acquire the fuel.

4.5.2 Initiative rationale

As Canada is a global leader in the use of sustainable practices and certification in its agricultural and forestry sectors, biojet from domestic feedstock sources holds the greatest potential for enabling carbon neutral growth of the Canadian aviation sector. The efficient use of existing downstream infrastructure

(e.g., blending and storage terminals, pipelines, and airport distribution & hydrant systems) are conditions precedent to wide scale biojet use. The functional integration into the downstream supply chain will be a key enabling factor for the uptake of meaningful volumes of biojet by the aviation sector.

4.5.3 Expected impacts

The Initiative is intended to achieve the following:

Demonstrate the operational feasibility of biojet in the domestic jet fuel supply system using existing delivery infrastructure (e.g., co mingled airport fuel system) to directly support carbon neutral growth of the Canadian aviation sector beyond 2020. Approximately 400 thousand litres of biojet made from certified sustainable Canadian oleochemical feedstocks will be blended into an airport fuel system. The Initiative will yield an operational report on fuel system integration in a Canadian context, implementation results of GHG and sustainability attribute accounting, and other areas of project research focus.

Validate Canadian biojet supply chain elements (e.g., quantitative feedstock availability, sustainability certification, biojet integration in the jet fuel supply system, quantify regulatory/policy options) to enable a feasibility assessment for private sector investment in commercial scale biojet production in Canada.

Catalyze the development of the domestic biojet sector by using HEFA biojet as an enabling mechanism to create market access for low carbon renewable jet fuel, and drive research, development, and commercialization of advanced biofuel feedstocks and conversion technologies beyond the 2020 timeframe.

Generate hands-on experience with biojet handling and integration to develop best practices in a Canadian context.

4.5.4 Supply chain expertise

The CBSCI team includes experts from a variety of disciplines and sectors, strategically selected for their contributions along the biojet fuel value chain. Relevant areas of expertise include: biomass supply chain and conversion to biofuel (BioFuelNetCanada, ASCENT (FAA)), fuel procurement and distribution (SkyNRG), engines and combustion (University of Toronto, ASCENT (FAA)), commercial end use (Air Canada, Boeing), renewable fuel and carbon policy (Queen's University, Transport Canada, National

Research Council), emissions lifecycle assessment modeling (McGill University, Fraunhofer Institute), guidance materials and best practices (IATA, CAAFI), and market development for commercial investment in the emerging biojet sector (Waterfall Group). Waterfall Group will be project lead for the CBSCI.

4.6 Renewable non-biogenic fuels as potential enablers of emissions reduction and long-term energy supply security

4.6.1 Background

The expected continued growth in air traffic and the associated increasing fuel demand poses two fundamental challenges for civil aviation:

- To mitigate the aviation sector's impact on climate change
- To ensure the security of future fuel supply

In order to ultimately meet both challenges, a paradigm shift from the current fossil (finite) to a future renewable energy basis is required. Consequently, interest of aviation in renewable fuels has strongly increased over the past years. As in road transport, all renewable fuels used so far are biofuels, *i.e.* produced from biogenic feedstock (biomass). The reason is simply that biomass represents an abundant and energy-rich carbonaceous material that can be fed into various chemical processes yielding biogenic fuels or chemicals.

However, several serious risks are associated with the energetic use of biomass. A central limitation of biomass production lies in the low energy efficiency of photosynthesis (the efficiency of the conversion of light energy into chemically stored energy). The theoretical limit of this efficiency ranges from 4.6% for so-called C3 plants to 6% for C4 plants⁷. However, under natural conditions, only photosynthetic efficiencies of about 1% are achieved. Downstream conversion and refining steps result in only a fraction of this energy being yielded in the form of liquid fuels in the end of the production chain. The low overall energy efficiency translates into an inefficient use of inputs and resources, *e.g.* freshwater, fertilizers, land and process energy.

A growing awareness of these issues has led to a broadening of scope in the search for scalable and

sustainable production pathways towards liquid fuels: Instead of considering biomass as the only viable renewable energy feedstock, the more general question of how to most efficiently use the ultimate form of primary energy, *i.e.* solar energy, to produce liquid hydrocarbon fuels is moving into the focus of scientific and industrial interest.

4.6.2 The process

The ultimate task is to apply solar energy to “re-energize” the products of combustion, water (H₂O) and carbon dioxide (CO₂), into energy-rich compounds that can be further converted into liquid hydrocarbon fuels. There are three general approaches to accomplish this task, *i.e.* through photochemical, electrochemical and thermochemical processes (Figure).

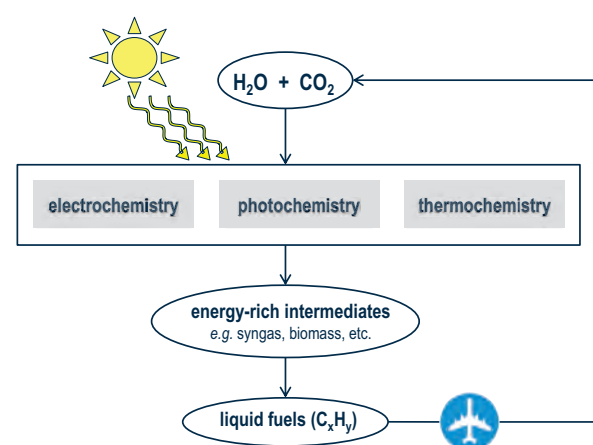


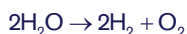
Figure 9 – Closed carbon-loop of renewable fuel production: Water and carbon dioxide as products of combustion can “re-energized” by solar energy via photochemical, electrochemical and thermochemical approaches.

The most prominent representative of photochemical processes is natural photosynthesis, successfully applied at vast scale since billions of years and responsible for the production of biomass and also of all fossil carbonaceous energy carriers. But there are also substantial R&D efforts dedicated to the design of “artificial” photosynthetic systems, where solar energy is harnessed through photochemical excitation to drive the involved endergonic redox reactions. However, the focus of the present article lies on electrochemical and thermochemical processes.

Utilizing renewable electricity represents a straightforward approach to provide the required driving force for re-energizing water and carbon dioxide. In a first

7. X.-G. Zhu, S. P. Long, and D. R. Ort, *Curr. Opin. Biotechnol.* **2008**, 19(2), 153–159.

step, electrolysis of water is used to split water into molecular hydrogen (H_2) and oxygen (O_2):



This step is industrially established and allows energy conversion efficiencies of 80 – 85%. The energy-rich hydrogen gas can be used to activate carbon dioxide via reduction to carbon monoxide (CO) in the so-called *reverse water-gas shift reaction*:

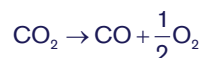
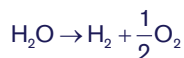


Mixtures of hydrogen and carbon monoxide, commonly referred to as *synthesis gas*, can be converted into various hydrocarbon products in a well developed industrial process, the *Fischer–Tropsch synthesis* (FT synthesis):

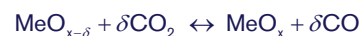


The FT products, here indicated as “ CH_2 ” building block of a hydrocarbon product mixture of various chain lengths can be converted via standard refinery technologies into jet fuel (or other types of liquid fuel and chemicals). This production pathway towards liquid hydrocarbon products is generally referred to as *Power-to-Liquid* (PtL). The PtL process can utilize solar energy either directly, e.g. via photovoltaics, or indirectly, e.g. via wind power generation.

In the third general approach to harness solar energy for fuel production, the thermochemical pathway, the chemical processes are driven by thermal energy input: The system is “simply” heated up. The principle of using high-temperature heat derived from concentrated solar irradiation is already industrially established in concentrated solar power (CSP) plants. The required concentration of solar irradiation is achieved through a mirror system. In case of solar-thermal fuel production, a reactor is located in the focal point, where the central reactions take place, i.e. splitting of water and carbon dioxide into a gaseous mixture of hydrogen and carbon monoxide (synthesis gas) as well as oxygen (O_2):



As both, water and carbon dioxide, represent highly stable compounds, thermolytic splitting requires very high temperatures, exceeding 2500 K. Furthermore, direct splitting poses the problem of separating the inherently formed oxygen from the desired synthesis gas. Therefore, R&D efforts focus on two-step thermochemical cycles where the splitting reaction is mediated by metal oxides (here denoted MeO_x)⁸:



During reduction, the reactor containing the metal oxide is heated to 1700 K and above under reduced oxygen partial pressure, resulting in partial loss of oxygen (reduction) which is removed upon formation. In the second step, the partially reduced metal oxide is reacted at lowered temperatures with carbon dioxide and water (oxidation), thereby forming synthesis gas and regenerating the metal oxide. As in case of the PtL pathway, the yielded synthesis gas can be converted into liquid fuels via Fischer–Tropsch synthesis.

The process of solar-thermochemical production of liquid fuels is often termed *Sunlight-to-Liquid* (StL). While still in a stage of low technical maturity, the entire production chain has recently been demonstrated for the first time in the course of the EU-FP7 project *SOLAR-JET*⁹ with the production of “solar kerosene” (Figure 1). The scale-up of this promising technology, in particular the transfer from laboratory to an industrially relevant environment will be subject to a follow-up EU-H2020 project to be launched in the beginning of 2016.

8. M. Romero and A. Steinfeld, *Energy Environ. Sci.* **2012**, 5, 9234–9245.

9. <http://www.solar-jet.aero>



Figure 10 – Solar-thermochemical reactor at ETH Zurich (left picture) that was used for the first-ever production of “solar kerosene” in the EU-FP7 project SOLAR-JET. Products of the StL (Sun-to-Liquid) process are shown in the right picture (from left to right flask): Heavy FT products (waxes), liquid FT products and middle distillate (jet fuel range) products of hydrocracked sample of FT waxes. The bright green color of the latter (“solar kerosene”) probably originates from trace amounts of metal catalysts from the hydrocracking procedure. (Source: <http://www.solar-jet.aero>).

4.6.3 Energy efficiency

The critical issues associated with biofuels mostly originate from the low energy efficiency of photosynthesis. Energy efficiency is consequently a key performance parameter for the development of renewable non-biogenic production pathways. Taking into account the energy efficiencies of the single steps of the PtL process for current state-of-the-art technologies, e.g. 20% for photovoltaic electricity generation, 80 – 85% for low-temperature electrolysis and 60% for the Fischer–Tropsch synthesis, an overall energy efficiency of about 10% seems realistic.

Being technologically less mature, the energy efficiency of the StL process, specifically of the thermochemical splitting reaction, can only be estimated as efficiency *potential*. Considering energy efficiencies of 50 – 85% for the concentration of solar irradiation, of 20 – 30% for the thermochemical reaction step (the thermodynamic limit lies well above 30%) and again 60% for the FT synthesis, an overall process efficiency of 6 – 15% could be reached.

So in terms of solar-to-fuel energy efficiency, both processes (PtL and StL) potentially surpass natural photosynthesis by about one order of magnitude.

4.6.4 Production potential

The question “How much can be produced?” is key with respect to the potential role of alternative fuels in facilitating future aviation’s GHG emissions reduction targets and energy supply security. In this context it is fortunate, that the energy flow reaching Earth’s surface in the form solar electromagnetic radiation is vast and by far exceeding mankind’s energy needs. For example, the geo-scientific evaluation¹⁰ of the global potential for solar-thermal electricity production yielded the enormous value of 3,000,000 TWh_{el} yr⁻¹. The global potential for power generation from wind energy (essentially solar energy converted into kinetic energy of the atmosphere) has been estimated¹¹ to be in the range of 160,000 – 600,000 TWh_{el} yr⁻¹. This compares with a current annual demand for electricity of 23,000 TWh_{el}¹². It seems therefore reasonable to infer that, next to electricity generation, there is huge potential for solar-powered liquid fuel production.

For example, assuming an energy efficiency of 10% of PtL production (see above), 6000 TWh_{el} yr⁻¹ would be sufficient to meet the jet fuel demand of the entire global fleet of currently 250 Mt. And assuming an area-specific annual yield of 50,000 L ha⁻¹ for StL production at locations of intense solar irradiation, even single countries could theoretically

10. F. Trieb, C. Schillings, M. O. Sullivan, T. Pregger, and C. Hoyer-Klick, *Global Potential of Concentrating Solar Power*, in *SolarPaces. Conference Berlin*, 2009.

11. L. M. Miller, F. Gans, and A. Kleidon, *Earth Syst. Dyn.* **2011**, 2, 1–12.

12. *Key World Energy Statistics 2014*, OECD/IEA, 2014.

provide jet fuel quantities meeting the global demand: For example, incident solar irradiation in Algeria is in principle sufficient to meet the current global jet fuel demand fifteen times.

4.6.5 Environmental performance

A highly favorable environmental performance, particularly in terms of specific GHG emissions, is mandatory for any renewable fuel, considering the ambitious emissions reduction targets of the sector.

Simplistically assuming the generation of electricity as the only source of GHG emissions in the production pathway of PtL fuels, favorable GHG emissions of $11 \text{ gCO}_{2\text{-eq}} \text{ kWh}_{\text{el}}^{-1}$ for wind power generation would translate into specific GHG emissions of $6 \text{ gCO}_{2\text{-eq}} \text{ MJ}^{-1}$ of PtL jet fuel. This corresponds to a reduction of more than -90% compared to conventional jet fuel ($87.5 \text{ gCO}_{2\text{-eq}} \text{ MJ}^{-1}$). However, emission sources other than electricity generation along the process chain will inevitably increase the overall carbon footprint of PtL fuels. Nevertheless, a highly advantageous GHG emissions profile can be expected for PtL fuels.

Information on the GHG emissions reduction potential of StL fuels is yet scarce. A detailed analysis of the environmental performance of StL has been carried out within the EU-FP7 project SOLAR-JET and will be published soon. Results of this study indicate a potentially very favorable carbon footprint of StL fuels. As is true for most kinds of lifecycle assessments, this footprint strongly depends on the underlying assumptions. In this respect, the source of carbon dioxide is of particular importance: A truly sustainable fuel production is only possible if the feedstock carbon dioxide is extracted from sustainable sources, e.g. from waste streams of biogenic processes, such as fermentation, or directly from air capture. This is true for all pathways that depend on carbon dioxide as feedstock, such as StL and PtL, but also microalgae-based technologies.

The high potential energy efficiencies of PtL and StL production translate into a low demand of land: An area-specific yield of $50,000 \text{ L ha}^{-1}$ of StL fuels under favorable conditions surpasses the yields of biofuels by at least one order of magnitude. Moreover, no arable land is required. For example, the site requirements for StL production, i.e. high solar irradiation and low atmospheric humidity, are complementary to the

requirements of agricultural production, minimizing the risk of competition for land.

4.6.6 Economic competitiveness

As with all renewable fuel production pathways currently under development, costs of production are the most critical issue with respect to large-scale deployment: Renewable aviation fuels are economically not competitive at the moment. However, there is potential for improvement. In case of PtL fuels, costs of production crucially depend on the costs of electricity generation. For example, assuming levelized costs of electricity of $5 \text{ \$ct kWh}^{-1}$ and an electricity-to-fuel energy efficiency of 50% , electricity demand alone would result in costs of about $160 \text{ \$bbl}^{-1}$ of fuel, compared with a current price of $61 \text{ \$bbl}^{-1}$ for conventional jet fuel¹³. Given the impressive development of cost reduction of renewable electricity generation over the past years, some further improvement can be expected. In addition, significant improvements in energy conversion efficiency could be achieved through development of high-temperature electrolysis, as targeted in the German research project “sunfire”¹⁴.

Little information is available on the potential economic performance of StL fuels. As in case of GHG emissions, a detailed analysis was carried out within the SOLAR-JET project and will be published soon. A crucial cost driver in StL production was found to be the heavy investment required for constructing the solar concentration facility. The greatest potential for cost reduction lies here in improving the energy efficiency along the process chain, since an increased efficiency directly translates into a decreased required scale of the solar concentration field, and thus into lower costs of investment. Given the current low level of maturity of StL technology and its large efficiency potential of $6 - 15\%$ (see above), large improvements in efficiency can be expected in the future. It is estimated that a solar-to-fuel energy conversion efficiency of about $5 - 10\%$ has to be achieved in order to enable economic competitiveness for long-term applications.

4.6.7 Key findings

Energy supply security and GHG emissions reduction are key challenges for future aviation. Both challenges can only be met through a paradigm shift

13. IATA Fuel Price Analysis (<http://www.iata.org/publications/economics/fuel-monitor/Pages/price-analysis.aspx>), accessed Nov 17, 2015.

14. <http://www.sunfire.de>

from the current fossil to a future renewable energy basis. While large-scale utilization of biomass for fuel production poses environmental and social risks, Power-to-Liquid (PtL) and Sun-to-Liquid (StL) fuel pathways enable the technical conversion of solar energy into renewable liquid fuels without the need for intermediate biomass production. Advantages of these pathways are potentially very favorable carbon footprints, low land requirements (in particular, no need for use of arable land) as well as vast production potentials. Risks are associated with the current low maturity especially of the StL technology and the

required enhancement of energy conversion efficiency. However, both options offer potentials for substantial improvements, specifically in terms of decreasing costs of renewable electricity generation and more efficient electrolytic energy conversion for PtL as well as improved energy conversion efficiency of the thermochemical reaction system for StL. Both, PtL and StL, represent highly attractive long-term options for meeting the key challenges of future aviation, namely achieving a substantial reduction of GHG emissions and ensuring energy supply security.

5. Notable developments

5

5.1 Summary

While many notable developments have occurred in alternative aviation fuels over the past 12 months, a few examples have been detailed.

- Indonesia is assessing the merits of different policies and support mechanisms for alternative fuels with the hope to share learnings which the industry can benefit from.
- IATA held a dedicated symposium for alternative fuels, immediately following the traditional IATA fuel forum in Cancun, Mexico.
- FEDEX has joined the list of airlines committing to alternative jet fuel off-take agreements, using Red Rock Biofuels as their supplier.
- The Japanese initiative for next generation aviation fuels released a roadmap for developing an alternative fuels industry with particular emphasis on the 2020 Tokyo Olympics.
- China's first commercial passenger flight was performed by Hainan Airlines with the fuel produced from waste cooking oil by Sinopec.
- The South African Airways Group (SAA) developed a comprehensive 10 year strategic plan to comply with industry goals and to materially reduce CO₂ emissions including project Solaris which will produce alternative jet fuel from tobacco plants.

5.2 The need of Public Policies and global coordinated approaches for the deployment of Sustainable Aviation Fuels: The case-study of Indonesia.

5.2.1 Background

The International Civil Aviation Organisation (ICAO) has repeatedly encouraged Member States to foster public policies for the promotion of sustainable aviation fuels (SAF), as part of the *Basket of Measures* to achieve the global air transport industry climate change goals.

Back in 2009, the first International Conference on Aviation and Alternative Fuels (CAAF) organized by ICAO, agreed encouraging Member States “to establish policies that support the use of sustainable alternative aviation fuels, ensure that such fuels are available to aviation and avoid unwanted or negative side effects, which could compromise the environmental benefits of alternative fuels”;

One year later, the ICAO Assembly Resolution A37-19, requested Member States to “develop policy actions to accelerate the appropriate development, deployment and use of sustainable alternative fuels for aviation”. Then again in 2013 a new Assembly Resolution A38-18 requested States to “set a coordinated approach in their national administrations in order to develop policy actions to accelerate the appropriate development, deployment and use of sustainable alternative fuels for aviation, in accordance with their national circumstances”;

Nevertheless, despite the substantial accomplishments in the technical maturity of SAF achieved throughout the last years, still has not reached price competitiveness with fossil aviation fuel and existing policies have not been sufficient to enable its commercial availability and industrial deployment at large scale, with the acknowledgeable exemption of a few industrial case-studies worldwide currently under development. IATA would like to acknowledge the contribution of Cesar Velarde to this section.

5.2.2 The need of public policies: The case of Indonesia's Sustainable Aviation Fuel's national plan

As identified by the work of the ICAO SUSTAF Group (2013) a priority for the deployment of sustainable alternative fuels in aviation is to create a long-term market perspective and address the initial price gap with conventional jet fuel in order to initiate viable commercial production. A first step in that direction would be for States to include sustainable aviation fuels in their global renewable energy and biofuels policies.

That is currently the case of Indonesia: Its Ministry of Energy and Mineral resources, in close partnership with its Ministry of Transportation, has included Aviation within an ambitious national renewable energy policy for the transport sector, establishing a Bio Jet-Fuel mandatory use of 2% by 2018, and the objective of increasing it to 3% by 2020 and to 5% by 2025. Such policy is a key element of Indonesia's State Action Plan to reduce Aviation GHG Emissions, delivered to ICAO by Assembly requests.

As a result, the Indonesia government is currently working together with industry and academic stakeholders to build up the necessary industrial production capacity and to develop a full value chain able to be compliant with internationally recognized sustainability standards.

On that regulatory and industrial process, Indonesia government has, from the very beginning, involved its national airlines as well as IATA through the Aviation Biofuels and Renewable Energy Task Force (ABRETF), in order to implement such roadmap in permanent consultation with the affected sector. Main Indonesian airlines have provided their support and

cooperation to the Government for the establishment of such national policy, in order to contribute to the country's Climate Change objectives included on the above mentioned Action Plan.

The main concern of the airlines is whether the possible fuel cost increase can impact their competitiveness and currently IATA is cooperating with the Indonesian Directorate General of Civil Aviation to conduct an economic impact analysis on the air travel demand elasticity, and on that basis identify options to minimize any potential risks for the sector.

This is the first case worldwide in which a renewable energy mandate for transport sector will include aviation. Other policy options or a combination of instruments can also be an effective way to overcome economic barriers for the commercial scale-up of SAF. In any case, without more targeted public policies, is not likely to happen at a global scale.

5.2.3 The need of global cooperation and coordinated approaches

ICAO and the global aviation industry have identified SAF as a fundamental mean to achieve its ambitious GHG emissions reductions objectives by 2020 and 2050. But its global availability can only be attained through incentivizing large-scale investments and reducing costs and capital risks in different world regions.

Industry and governments will need to collaborate to ensure that supporting policies are put in place, and that those are stable (with at least a 10 years horizon to assure investments return) and when establishing regulatory requirements to international aviation, be done in dialogue with the global community and as possible be accompanied by mutually recognized mechanisms.

With a lack of globally coordinated approaches, a plethora of different regulations and requirements may affect the competitiveness of the industry, and result in economic and administrative burdens for complying with different requirements.

Policy and supporting mechanisms developed by some States, when demonstrated to be effective, can serve as references for other Member States aiming to implement similar policies; so as well a global dialogue is necessary to share lessons learned and avoid repeating mistakes of unsuccessful initiatives.

ICAO is permanently working to facilitate those exchanges and global coordination and also many States have established bilateral or multilateral cooperation frameworks in this field.

As an example, Indonesia and the United States of America signed a cooperation agreement in October 2015 to contribute to such exchanges. They have also, together with IATA, encouraged ICAO on its Committee on Aviation and Environmental Protection (CAEP) to consider developing guidance material for Member States aiming to develop policy frameworks for SAF.

5.2.4 Conclusion

Renewable Energy policies for transportation have been effective in many countries through the establishment of mandates, fiscal incentives or other mechanisms, but mainly applied only to road transport. It is important to include SAF in specific alternative fuels policies of States to make them become available at global commercial scale. Actually, aviation has no alternative to liquid fuels in a foreseeable future, unlike road transportation.

A certain level of convergence between national policies and the definition of mechanisms for interoperability and mutual recognition should be promoted by States specially when affecting international aviation, and global cooperation among countries or regions and within ICAO are also key needs for achieving a future global supply of sustainable aviation fuels.

5.3 1st IATA Alternative Fuel Symposium:

5.3.1 Background

In conjunction with its annual Aviation Fuel Forum, IATA recently held the 1st Alternative Fuel Symposium in Cancún, Mexico. Around 80 participants from the aviation and the alternative fuel sector, as well as from traditional oil companies, came together for this first-of-its-kind event. In contrast to the already numerous conferences covering aviation biofuels, the symposium had a clear focus on directly bringing together airline customers and alternative fuel suppliers with each other and also with business facilitators helping to remove the remaining barriers to alternative jet fuel deployment. Over 20 international leaders and experts in the field of alternative aviation fuels presented and discussed views and shared case studies.

5.3.2 Content of the symposium

Aline Pillan from the French Civil Aviation Authority stressed the importance of sustainable fuels for meeting aviation's carbon reduction targets in the light of the upcoming UN Climate Change Conference in Paris, starting at the end of this month, and the ICAO Assembly in 2016. Steve Csonka from the Commercial Aviation Alternative Fuel Initiative (CAAFI) highlighted the variety of alternative jet fuel production pathways, which can improve the chances of finding economically viable feedstock options for each world region. Currently there are 16 new pathways in the certification process adding to the three that are already certified for commercial flight use.

A wide scope of fuel options were presented at the symposium, ranging from Fulcrum's municipal waste-based fuel, which will start to be supplied to United Airlines and Cathay Pacific in the next years in quantities of over 100 million gallons per year, to a new process developed by Joule Unlimited based on sunlight-absorbing bacteria, which could make use of the large unused areas of desert regions.

Biofuel delivery to Los Angeles International Airport as a result of the long-term off-take agreement between United Airlines and AltAir is in its final preparation phase and planned to start before the end of 2015. The prospect of commercial success, along with a strong positive impact of biofuel production on social sustainability and rural development, is likely to be achieved through South African Airways' Solaris project, whose objective is jet fuel production from energy tobacco plants. This project, said a representative, fitted perfectly into South Africa's development goals by creating new livelihoods for smallholder farmers.

It was stressed by speakers that alternative jet fuel deployment is a highly interdisciplinary business that strongly relies on multi-stakeholder partnerships at national and global level beyond just suppliers and customers. Both the big aircraft manufacturers, Airbus and Boeing, are now engaged with many airlines and governments across the world to support building up local supply chains. The EU-funded ITAKA project is investigating the challenges of production, logistics and sustainability, and aims to build up and test an airport biofuel supply chain.

To bridge the 'valley of death' that alternative jet fuels – like many young technologies – are facing, unconventional ideas are necessary. One novel concept covered at the symposium was SkyNRG's Fly Green Fund, which allows environmentally conscious corpo-

rate air travel customers to invest in sustainable fuels and so help overcome the prohibitive price gap with fossil fuel. Similarly, the Carbon War Room, founded by Sir Richard Branson, promoted a more active role of airports as supply centres for biofuels.

5.3.3 Future events and major sponsors

The symposium spotlighted the high level of dedication of the aviation alternative fuel community in overcoming obstacles to make deployment happen. An update on developments and more case studies are expected at the second Alternative Fuel Symposium, which is now intended to be held every year. IATA gratefully acknowledges the support of the following companies as sponsors of the 1st Alternative Fuel Symposium.

- ✦ Gold Sponsor: Climate KIC
- ✦ Silver Sponsor: Fulcrum Bioenergy and the Inter-American Development Bank
- ✦ Bronze Sponsor: The Round Table on Sustainable Biomaterials and SkyNRG

5.4 FEDEX

5.4.1 Background

Starting in 2017, the FedEx Oakland hub will mix up our first supply of alternative jet fuel. Half Jet A/half biofuel, the first six million gallons will be blended on site, meeting current aviation regulations and ultimately producing at least 48 million gallons over the term. IATA would like to acknowledge the contribution of David Jensen to this section.

You may have heard about the diverse ingredients used to produce these fuels – algae, tree pulp, even scrub brush. But this is just the beginning of the story. Early off-take agreements, like ours with [Red Rock Biofuels](#), signal the start of a new industry. One that has the potential to help farmers and start-ups around the world turn waste into new forms of clean energy with some surprising ripple effects.

5.4.2 Forest Waste to Fuels

Take Red Rock. Their model uses waste woody biomass (branches, bark or pine needles) from timber operations and a saw mill in Lakeview, Oregon. At the local level, Red Rock anticipates that their biofuel

refinery will create about 100 jobs – 30 at the plant and about 70 in woods and transport. These smaller scale facilities are perfect for communities like Lakeview, allowing them to grow with the market as production is increased.

At the regional level, Red Rock, the USDA, the Forestry Service, and NGOs work together to better manage forestry health. Harvesting timber inevitably leaves unused material behind in the forest. This waste, coupled with natural waste generated by the forest itself, equates to thermal mass that significantly adds to the risk for forest fires started by man or nature. Also, there is a problem with a nasty South American beetle infestation killing trees. The Forestry Service estimates at least half the trees west of the Rockies suffer from “beetle kill,” creating even more risk for fire damage.

At the global level, turning timber waste into fuel helps FedEx reduce carbon emissions and deliver your packages more sustainably.

5.4.3 Farm Waste to Flight

Models like these also create an interesting possible path forward for FedEx to deliver more to communities and give back. We travel to airports all over the world. Helping others replicate this in a waste-to-biofuel model seeds new industries around these airports. The synthetic renewable crude produced could also be used for chemicals, pharmaceuticals, plastics, and heating oil. So one area’s waste and one flight could grow into a sustainable local industry and could create a variety of products and jobs in these communities.

This industry is still in its infancy, but with the help of government-backed research grants and loans, the barriers of the past few years are eroding. More companies are solving their “scale-up” issues and becoming cost competitive.

Exploring waste as a business model opens up a whole new route of possibilities. FedEx also is looking at alternative fuel companies that utilize waste oils like fats and greases, agricultural waste such as stover that remains after the food portions have been harvested, municipal solid waste, natural gas, and algae, to name a few.

As this industry continues to transition from the laboratory to competitive alternative fuels, we can expect to see more aviation industry announcements in the coming years!



5.5 Japan plans biofuel in Aviation during 2020 Olympics

Japan will be hosting the 2020 Olympics and Paralympic Games in Tokyo when the country plans to use sustainable aviation fuel. Boeing has partnered with Japanese aviation industry stakeholders to develop sustainable aviation biofuel for flights during these two global events.

A five-year “roadmap” to develop biofuel by 2020 has been prepared by Next Generation Aviation Fuels (INAF) – which is a consortium of 46 organizations including Boeing, ANA (All Nippon Airways), Japan Airlines, Nippon Cargo Airlines, Japan’s government and the University of Tokyo.

The 2020 global event is a time when millions of people from across the world will be visiting Japan and therefore it’s a good time to introduce aviation biofuel.

The US Department of Energy claims that use of sustainably produced biofuel reduces lifecycle carbon dioxide emissions by 50 to 80% compared to conventional petroleum fuel.

Some of aviation biofuel feedstock that Japan is looking at are – municipal solid waste, plant oils and animal fats, used cooking oil, algae, cellulosic biomass and residues from the wood products industry.

INAF’s roadmap covers the entire biofuel supply chain from procurement of raw materials, production of sustainable aviation fuel, to blending biofuel with conventional petroleum jet fuel and how biofuel will be incorporated into an airport’s fueling infrastructure.

Meanwhile Boeing already has active biofuel projects in the US, Australia, Brazil, Africa, China, Europe, Middle East and Southeast Asia.

5.6 Hainan Airlines Biofuel Passenger Flight

On March 21st 2015, supported by Civil Aviation Administration of China (CAAC), Hainan Airlines conducted China’s first passenger flight with sustainable aviation biofuel by working with Boeing, the world’s largest aerospace company, and Sinopec, China’s largest integrated energy and chemical company.

The regularly scheduled Hainan Airlines flight – which carried more than 100 passengers from Shanghai to Beijing in a Boeing Next-Generation 737-800 – used biofuel made by Sinopec from waste cooking oil collected from restaurants in China. Both of the 737's CFM56-7B engines were powered by a fuel blend of about 50 percent aviation biofuel mixed with conventional petroleum jet fuel. It was estimated that 500 million gallons (1.8 billion liters) of biofuel could be made annually in China from used cooking oil.

The flight was a significant achievement for several reasons. China's civil aviation system and airlines have grown and will continue to grow rapidly to meet increasing demand for domestic and international air travel. According to Boeing 2015 Current Market Outlook, China will require more than 6,000 new airplanes by 2033 to meet fast-growing passenger demand for domestic and international air travel.

Concurrently, there is an increasing focus globally and in China on reducing the commercial aviation industry's carbon dioxide (CO₂) emissions. Sustainably produced biofuel will play a crucial role in meeting this environmental objective because it reduces carbon emissions by 50 to 80 percent through its lifecycle. In addition, biofuel will help reduce soot emissions by 50 percent compared to petroleum. By furthering the use of sustainable biofuel in aviation, our industry will support aviation's growth while also meeting industry goals to reduce carbon emissions and pollution.

In that context, Hainan's biofuel passenger flight was a key environmental milestone for China's commercial aviation industry as it demonstrated the desire across sectors to promote aviation biofuel development and normalize its use in China. The flight also highlighted the opportunity for a regional supply chain – from producers to the end users, including passengers – that is ready to support routine aviation biofuel use in regularly scheduled flights.

Sinopec biofuels and its production were approved by CAAC in 2014. The successful completion of the flight in 2015 was due to great teamwork among the three companies on biofuel blending and fueling, fuels

property evaluation and compliance with airworthiness regulations.

Passengers also provided positive feedback about the flight. They were informed prior to the flight that the airplane would be fueled by a biofuel blend and provided with more information about the fuel during the flight.

As a fast-growing domestic and international carrier, Hainan Airlines' operation and activities are shaped by its philosophy of sustainable development and Corporate Social Responsibility. Hainan Airlines has committed to Energy Conservation and Emission Reduction since 2008, with specific efforts to introduce a new, more fuel-efficient fleet that includes 787 Dreamliners and to optimize operation efficiency to reduce energy use from gate to gate. In 2013, Hainan has further incorporated "green aviation" and "low carbon operation" into its corporate strategies.

Hainan Airlines recognizes aviation biofuels as an important element to support the sustainable growth of the aviation industry. This flight emphasizes its environmental commitment by joining efforts to show that aviation biofuel can play a safe and effective role in China's air transport system. Hainan would join the other industry stakeholders in China to devote collective efforts to promote the commercial use of biofuels in regular flights, through technology development and policy support to reduce the cost of biofuel and ensure it is price-competitive with petroleum.

As part of Boeing's commitment to protect the environment and support long-term sustainable growth for commercial aviation, the company partners globally with airlines, governments, research institutions, fuel companies and others to develop sustainable aviation biofuel. Boeing has active biofuel projects in the U.S., Australia, Brazil, Canada, China, Europe, Middle East, South Africa and Southeast Asia.

Sinopec's efforts on aviation biofuel R&D started in 2009. Their aviation biofuel refinery in Zhenhai, Zhejiang province with self-developed technology is the first facility in China with the capability to support biofuel using in the commercial flights.



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5.7 South African Airways Biofuel Program-Project Solaris

5.7.1 Background

The South African Airways Group (SAA) developed a comprehensive 10 year strategic plan to comply with industry goals and to materially reduce CO₂ emissions. As emissions from fuel constitute roughly 96% of all emissions for the Group, it was clear that a specific intervention would be needed to address these emissions and the only effective measure that would ensure a substantive reduction would be a bio fuel.

SAA-not having expertise in biofuels-sought out a competent, experienced and reliable partner to understand the landscape and to gain knowledge on the global biofuel developments. SAA and the Boeing Company then entered into a partnership agreement to explore the potential for biofuels in South and Southern Africa. A comprehensive analysis of the available biomass in the region was then carried out to determine where to focus attention.

At this stage the Boeing Company introduced SkyNRG into the equation as SkyNRG were investigating the viability of energy tobacco in South Africa. SkyNRG, Boeing and SAA then entered into a MOU to agree to work together to develop the energy tobacco project. SkyNRG then introduced Sunchem South Africa who is involved in all elements related to the development of seeds and the development and growth of the crop.

In the interim SAA was introduced to the Sustainable Alternative Fuel Users Group, SAFUG, by the Boeing Company and became a member. It was clear that the amount of differing certification schemes in operation around the world would make the landscape tricky to navigate in order to ensure recognition of sustainability in biofuels. It was therefore decided to pursue the most rigorous and robust standard, namely the Roundtable on Sustainable Biomaterials (RSB).

As the RSB standard contained a strong social component in addition to the sustainability requirements, it was even more attractive as South Africa has a large unemployment rate and a social development mandate from Government that needed to be considered. The RSB standard was thus an obvious choice.

IATA would like to acknowledge the contribution of Ian Cruickshank to this section.

5.7.2 Solaris

Solaris is an energy tobacco that is grown for its over-developed flowers and seed pods. These seed pods are cut off the plant and dried and pressed where two thirds is a seed cake suitable for an animal protein and the last third is oil that is suitable for processing into a biofuel. Plants can be harvested up to three times per season and research into uses of the remaining biomass have concluded that the plant can be utilised for co-gen purposes or to manufacture paper or cardboard. Solaris tobacco plants do not contain nicotine and are unsuitable for smoking.

Numerous growing conditions were tested with various irrigation types and a small dry-land trial was conducted. Plants were successfully grown by a variety of growers including commercial farmers and small hold cooperatives. Due to the social requirements of the country, small hold farmers will be a key element in the program.



5.7.3 Sustainability

Due to the nature of the South African agronomical and climatic landscape it has always been critical that any energy crop based fuel be sustainable and certified as such. South Africa is a water stressed country and net importer of a variety of foodstuffs so the food versus fuel debate and the water use required for the production of the crop were always going to be the biggest environmental hurdles to the project. The decision to obtain a sustainability certification was therefore critical to demonstrate that the plant could be produced in a sustainable way and the impact would be positive.

It was therefore decided that the RSB should be engaged to undertake a sustainability audit on the 2014/15 growing cycles to introduce sustainability practises into the growing of the crop in order for the crop to be successfully certified. The extra work and effort required to adhere to the standard was worthwhile and the RSB certification was granted in 2015.

Taking the sustainability benchmark even further, Boeing provided further funding for an in-depth three year study related to the effects of an energy crop to the country and the region and the impacts that this will have. This will be jointly undertaken by the RSB and the WWF-SA and will prove valuable and ground breaking in the pursuit of sustainable sources of biomass for biofuel production.

5.7.4 Future focus

In 2015 the focus of the project was the successful growing of the crop with an RSB certification for growing the crop sustainably and the subsequent processing of the seeds as this is a new crop that has not previously been grown and processed. Research into an effective method of processing is currently in focus with streamlining of the process expected to bring significant strength to the economics of the plant.

The plant oil is expected to be refined into a small quantity of bio jet fuel in order to conduct familiarisation flights to demonstrate to the South African flying public that the fuel is safe for use and viable as a bio fuel. The familiarisation flights will operate and standard scheduled flights in the SAA network and will carry fare paying passengers.

Further future development of the project will commence at the conclusion of the familiarisation flights in collaboration with the Government of South Africa who have a key role to play in ensuring that this project is able to expand rapidly. This project was chosen specifically for the wide ranging benefits and effects on the wider SA economy and for the benefits to the airline.

5.7.5 Benefits

The macro-economic and strategic effects of a large Solaris implementation include:

- job creation;
- reductions in foreign currency reserves required to purchase oil off shore;

-
- 7 retained earnings and tax revenues that remain within the country;
 - 7 security of supply of a crucial commodity; and
 - 7 a natural currency hedge against the volatilities in the oil and foreign currency markets that directly affect South Africans at a local level.

SAA would gain a reliable and local currency based, source of fuel that is sustainable and offers small energy gains over conventional fossil fuels. This will ensure that South Africa's aviation obligations in terms of CO₂ reductions will be met and exceeded while

adding valuable additions to the national economy by moving the source of oil from far-flung territories across the world to a local supply.

In this instance the low-technology and agronomically intense approach is best suited to the conditions and requirements prevalent within the country and is considered to be beneficial and a valuable addition to the economy over a high-technology solution that would not offer the same broad benefits directly to the population of the country or the region.



5

Glossary

Alternative fuel	= fuel from non-petroleum sources; the term “alternative fuels” includes biofuels
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, animal products etc.
Blend	= mixing of different types of fuel
Book and claim system	= accounting system where fuel use can be claimed anywhere in the world independent of where it is used
Butanol	= alcohol with a 4-carbon atom based carbon chain
Camelina	= oilseed plant that can be grown in crop rotation with other plants, e.g. wheat
Carbon footprint	= amount of net carbon dioxide emissions addressed to a specific product or activity
Carbon neutral	= with zero carbon footprint (CO ₂ emission = CO ₂ absorption)
Catalyst	= material that facilitates a chemical reaction
Cellulose	= organic compound consisting of linked D-glucose units
Density	= mass per unit volume
Drop-in fuel	= A fuel that is completely interchangeable and compatible with a particular conventional (typically petroleum-derived) fuel.
Ethanol	= drinkable alcohol with 2 carbon atoms
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
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
Hydrotreatment	= saturating and removing impurities in hydrocarbons using hydrogen
Hydroprocessing	= upgrading of oils with hydrogen, current technology in refineries
Lignin	= complex organic polymer commonly derived from wood and plant material
Jatropha	= genus of tropical oil plants used as a feedstock for biofuel
Marginal lands	= and with low levels of productivity, poor soil quality, and unsuitable for housing or other uses

Market-based mechanism	=	A measure that applies market principles in order to provide incentives to mitigate emissions; examples include, but are not limited to, emissions trading schemes and crediting systems.
Methanol	=	smallest alcohol with only 1 carbon atom and low specific energy
Meta-standard	=	framework standard consisting of different achievement levels available within a specific standard (e.g. a national sustainability standard) to be recognized for a broader objective
Offtake agreements	=	commitment from a customer to purchase a good (e.g. biojet fuel) in the future
Oil-crops	=	plants that produces oil, palm oil, jatropha oil, soybean oil, etc.
Paraffin	=	straight-chain alkaline hydrocarbons
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
Sustainable biomass	=	renewable biomass that is produced with low negative environmental and societal impact that does not compromise the ability of future generations to address their needs.
Waxes	=	solid long-chain carbon molecules

Acronyms

2BSvs	=	Biomass Biofuel Sustainability Voluntary Scheme
A4A	=	Airlines for America
ABRETF	=	Aviation Biofuels and Renewable Energy Task Force
ABRABA	=	Brazilian Alliance for Aviation Biofuels
ABT	=	Advanced Biochemicals (Thailand) Company
ACI	=	Airports Council International
AFTF	=	Alternative Fuels Task Force (in ICAO)
AIA	=	Aerospace Industries Association
aireg	=	Aviation Initiative Renewable Energy in Germany
AISAF	=	The Australian Initiative for Sustainable Aviation Fuels
ARS	=	Agricultural Research Service (USA)
ASCENT	=	Aviation Sustainability Center
ATAG	=	Air Transport Action Group
ATJ	=	Alcohol-to-Jet
BETO	=	BioEnergy Technologies Office
BMBF	=	German Federal Ministry of Education and Research
BMVI	=	German Federal Ministry of Transport and Digital Infrastructure
BRA	=	Brazilian Alliance for Aviation Biofuels
BRDI	=	Biomass Research and Development Initiative
BtL	=	Biomass-to-Liquid
CAAFI	=	Commercial Aviation Alternative Fuels Initiative (USA)
CAEP	=	Committee for Aviation and Environment Protection (in ICAO)
CAPEX	=	Capital Expenditure
CLEEN	=	Continuous Low-Energy, Emissions and Noise
CO	=	Carbon Monoxide
CO ₂	=	Carbon Dioxide
CoC	=	Chain of Custody
COP21	=	Conference of Parties 21 (UN climate conference in Paris, December 2015)
CPET	=	United Kingdom Central Point of Expertise for Timber (United Kingdom)
CSIRO	=	Commonwealth Scientific and Industrial Research Organization
DSHC	=	Direct Sugar to Hydrocarbon
DOD	=	Department of Defense (USA)
DOE	=	Department of Energy (USA)
EAG	=	Environment Advisory Group
EC	=	European Community
EISA	=	Energy Independence and Security Act (USA)
EPA	=	Environmental Protection Agency (USA)

EPAct	=	Energy Policy Act
ETS	=	Emissions Trading System
EU	=	European Union
FAA	=	Federal Aviation Administration
FQD	=	Fuel Quality Directive
FT	=	Fischer Tropsch
GAEC	=	Good Agricultural and Environmental Condition
GARDN	=	Green Aviation Research and Development Network (Canada)
GFAAF	=	Global Framework for Aviation Alternative Fuels
GHG	=	Greenhouse Gas
GMTF	=	Global Market-based Measure Technical Task Force (ICAO)
GREET	=	Argonne National Laboratory's Greenhouse Gases, Regulated Emissions and Energy Use in Transportation model
GtL	=	Gas-to-liquid
H ₂	=	hydrogen
HEFA	=	Hydrotreated Esters and Fatty Acids
IATA	=	International Air Transport Association
ICAO	=	International Civil Aviation Organization
IDB	=	Inter-American Development Bank
IEA	=	International Energy Agency
ILO	=	International Labour Organization
ILUC	=	Indirect land use change
IRR	=	Internal Rate of Return
ISCC	=	International Sustainability & Carbon Certification
ITAKA	=	Initiative Towards Sustainable Kerosene for Aviation
LUC	=	Land use change
MASBI	=	Midwest Aviation Sustainable Biofuels Initiative
MBM	=	Market Based Mechanism
MoU	=	Memorandum of Understanding
MRG	=	Monitoring and Reporting Guidelines
MRV	=	Monitoring, Reporting and Verification
MSW	=	Municipal Solid Waste
Mt	=	Megatonne
NASA	=	National Aeronautics and Space Administration (USA)
NIFA	=	National Institute of Food and Agriculture (USA)
NISA	=	Nordic Initiative for Sustainable Aviation
NO _x	=	Nitrogen Oxide
NPV	=	Net Present Value
NSW	=	New South Wales (Australia)
O ₂	=	Oxygen

PM	=	Particulate Matter
PNPB	=	Brazil National Production and Use of Biodiesel
PPP	=	public-private-partnerships
PtL	=	Power-to-liquid
R&D	=	Research and Development
RED	=	Renewable Energy Directive (EU)
RFS	=	Renewable Fuel Standard (USA)
RFS2	=	Renewable Fuel Standard 2 (USA)
RINs	=	Renewable Identification Numbers
RSB	=	Roundtable on Sustainable Biomaterials
RSPO	=	Roundtable on Sustainable Palm Oil
RVO	=	Renewable Fuel Volume Obligations
SAA	=	South African Airways
SABB	=	Sustainable Aviation Biofuels for Brazil
SAF	=	Sustainable Alternative Fuels
SAFN	=	Sustainable Aviation Fuels Northwest
SAFUG	=	Sustainable Aviation Fuel Users Group
SAJF	=	Sustainable Alternative Jet Fuel
SBG	=	Sustainable Bioenergy Group of SE4ALL
SE4ALL	=	United Nations Sustainable Energy for all Initiative
SENASA	=	Services and Studies for Air Navigation and Aeronautical Safety (Spain)
SIP	=	Renewable Synthesized Iso-Paraffinic
SKA	=	Synthetic Paraffinic Kerosene with Aromatics
StL	=	Sunlight-to-liquid
UCO	=	Used Cooking Oil
UCOME	=	Used Cooking Oil Methyl Ester
USD	=	US Dollar
WWF	=	World Wildlife Fund

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