IATA 2014 Report on Alternative Fuels

Effective December 2014
NOTICE

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

© International Air Transport Association. All Rights Reserved. No part of this publication may be reproduced, recast, reformatted or transmitted in any form by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system, without the prior written permission from:

Senior Vice President
Member & External Relations and
Corporate Secretary
International Air Transport Association
33, Route de l’Aéroport
1215 Geneva 15 Airport
Switzerland
Dear readers,

We have now been providing commercial airline services for 100 years and have, in that time, flown over 65 billion passengers. The next 65 billion passengers will board within just 15 years. There are many factors behind this growth in demand, from holidays to business or visiting friends and relatives, not to mention the need for the speedy transportation of perishable and high value goods which we have grown so accustomed. Most of the growth mirrors the development in emerging economies worldwide, but whilst this translates into a tremendous economic opportunity, it also exposes the rising challenge of growing in a sustainable manner. Sustainable alternative fuels can provide an excellent remedy to the environmental challenges of future growth.

As with all aspects of aviation, safety is the first priority when identifying replacements to conventional jet fuel. This is ensured by adhering to a strict set of fuel specifications that are required for conventional and emerging fuels alike. The process for approving new fuels is necessarily a slow one, given the impressive number of tests that must be passed, but we can proudly say that three different types of biojet fuel have been approved, the most recent in June 2014, and several more are in the works.

While cost remains a significant barrier to large-scale commercial production of aviation biofuels, there are a growing number of success stories, demonstrating that with a spirit of collaboration between policy makers, suppliers and airlines, it is possible to construct a viable business case. It is exciting to think United Airlines will be using an amount of sustainable aviation fuel from Los Angeles Airport as part of their regular operations from quarter one, 2015. Despite this progress, continued research and government support is essential to help increase the competitiveness at scale for this industry.

2014 has seen the third sustainable alternative jet fuel pathway referred to as Synthesized Iso-Paraffinic (SIP) fuel approved for blends up to 10%. A broadening portfolio of production pathways can only put downward pressure on prices. Further it is probable some of the additional pathways currently in the technical certification process will be approved over the next 12 months.

To discover more about the certification of new fuels, important progress towards harmonizing sustainability and accounting standards, the economic aspects of biojet fuel, multi-stakeholder initiatives 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 to this report.

I wish you happy reading.

Michael Gill
Director Aviation Environment
International Air Transport Association
Director – Aviation Environment
The alternative jet fuel sector has been extremely active in 2014. A total of 21 airlines have now used alternative fuel for a commercial flight. This is extremely impressive when just 5 or 6 years 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 into 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, 11 new initiatives have commenced in 2014 taking the total number of multi-stakeholder initiatives to 72. While price remains a challenge, there is growing evidence that with the support of appropriate policy mechanisms, innovative business cases can be developed to evolve production from demonstration scale to commercial scale.

The major headline of 2014 was Cathay Pacific signing a one billion USD 10 year off-take agreement with Fulcrum Bioenergy, the largest of any such agreement to date. At a State level Indonesia announced a 2% alternative jet fuel mandate to commence in 2016 and has begun to implement and action plan including the establishment of the “Aviation Biofuels and Renewable Energy Task Force (ABRETF)”.  

With a number of new production pathways currently in the ASTM International approval process 2015 is likely to certify 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, 2015 has the potential to be a significant year in the evolution of alternative jet fuel use in aviation.
Quick Facts

- Indonesia has introduced the first mandate for alternative jet fuel, commencing at 2% in 2016 and increasing to 5% in 2025.
- Over 200 flights were operated in 2014 using alternative jet fuel with the Brazilian company GOL being very active.
- KLM with supplier SkyNRG continued to pursue their efforts to deploy alternative fuel with a new series of 20 weekly intercontinental flights from Amsterdam to Aruba, while AirFrance have initiated a one-year series of weekly flights between Toulouse and Paris.
- ASTM International approved the third alternative jet fuel pathway in 2014. This new pathway is referred to as “Synthetic Iso-paraffin” from Fermented Hydroprocessed Sugar (SIP), and was formerly known as Direct-Sugar-to-Hydrocarbon.
- The approval of additional pathways is still ongoing. These include Alcohol-to-Jet, pyrolysis and catalytic cracking (Hydroprocessed Depolymerized Cellulosic Jet), catalytic hydrothermolysis and catalytic conversion of sugars plus the Boeing proposal to use green diesel at a low blending ratio.
- Early 2015 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.

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 harmonious standards. This will become increasing clear and important as the development of a potential global market based mechanism advances.
- A key element for achieving meaningful deployment is to bring the cost down towards parity with fossil fuel. This requires continued efficiency improvements in all facets of the supply and production process. Policies must continue to support and foster research and development but also evolve to address the challenge of crossing the ‘valley of death’. Cost competitiveness will only be achieved when alternative fuel production facilities can reach commercial scale. Policy is one ingredient that can provide the necessary bridge.
## Table of Contents

Alternative Fuels Foreword 2014 ................................................................. 1

### Summary

Quick Facts ........................................................................................................ 3
Recommendations ............................................................................................... 3

### 1. Overview of biojet fuels in 2014

1.1 Chapter summary .......................................................................................... 9
1.2 Introduction ..................................................................................................... 9
1.3 Technology developments ............................................................................. 10
1.4 Commercial production and use of sustainable alternative fuels .............. 10
1.5 Initiative for the development and deployment of alternative fuels .......... 11
1.6 The challenges ............................................................................................. 12
1.7 Achievements under ICAO .......................................................................... 14
1.8 Conclusion ................................................................................................... 15

### 2. Standard harmonisation and a future market based mechanism

2.1 Chapter Summary ........................................................................................ 17
2.2 Alternative fuels and a future market based mechanism ............................ 17
  2.2.1 Milestone decision at the 38th ICAO Assembly ....................................... 17
  2.2.2 ICAO’s work post Assembly ................................................................. 17
2.3 Global harmonization of sustainability standards and biofuel accounting methods ................................................................. 18
  2.3.1 Sustainability ....................................................................................... 18
  2.3.2 Comparison of key aspects of voluntary schemes ................................. 19
  2.3.3 Setting the sustainability ambition level ................................................ 20
  2.3.4 Two potential approaches ..................................................................... 20
  2.3.5 Accounting .......................................................................................... 21
  2.3.6 Chain of custody accounting approaches .............................................. 21

### 3. Sustainability

3.1 Chapter summary ........................................................................................... 23
3.2 Introduction .................................................................................................... 23
3.3 Roundtable on Sustainable Biomaterials ..................................................... 23
  3.3.1 Smallholders Initiative .......................................................................... 24
  3.3.2 Brazil Biofuels Platform ....................................................................... 25
  3.3.3 Sustainable Aviation Fuel User Group (SAFUG) ................................. 25
  3.3.4 Sustainable Aviation’s “Fuelling the Future” ......................................... 25
  3.3.5 Airbus and Virgin Australia Study ....................................................... 26
3.3.6 RSB Rated Best Biofuels Sustainability Certification Worldwide ............................................ 26
3.3.7 SSI Report States RSB Only Initiative Demonstrating 100% Coverage
of All Three SSI Greenhouse Gas Indicators ................................................................................ 26
3.3.8 Streamlining and Improvement of RSB Standard Continues ..................................................... 26

4. Economics ..................................................................................................................................... 27
4.1 Chapter summary ................................................................................................................................................. 27
4.2 Conventional jet fuel price development and incentives for alternative fuels
as points of reference ......................................................................................................................................... 27
4.2.1 Actual purchase prices ...................................................................................................................... 28
4.2.2 Theoretical purchase prices ............................................................................................................... 29
4.2.3 Cost drivers .......................................................................................................................................... 30
4.2.4 Future cost reductions ........................................................................................................................ 31
4.2.5 Concluding remarks ............................................................................................................................. 32
4.3 Valley of Death Economics: Sustainable Aviation Fuel .............................................................................. 32
4.3.1 Introduction ............................................................................................................................................ 32
4.3.2 About the “Valley of Death” ............................................................................................................... 33
4.3.3 Potential solutions to bridge the valley of death: ........................................................................... 37
4.3.4 Chapter references .............................................................................................................................. 40

5. National and International Biojet programs ......................................................................................... 41
5.1 Chapter summary ................................................................................................................................................. 41
5.2 The Indonesian Alternative Fuels and Renewable Energy Initiatives ....................................................... 41
5.2.1 Background and overview .................................................................................................................. 41
5.2.2 Objectives and timeframe .................................................................................................................. 42
5.2.3 Development of a policy and regulatory frameworks ...................................................................... 43
5.2.4 National stakeholders involvement ................................................................................................ 43
5.2.5 Feedstock & Sustainability ................................................................................................................ 44
5.2.6 ICAO Cooperation ............................................................................................................................... 44
5.3 The Air Transport Institute for Environmental Sustainability (AirTIES) Research Center ............ 45

6. Notable Developments ................................................................................................................................. 47
6.1 Chapter summary ................................................................................................................................................. 47
6.2 Driving Alternative Sustainable Aviation Fuels in Abu Dhabi .......................................................... 47
6.2.1 BIOjet Abu Dhabi: Flightpath to Sustainability .............................................................................. 47
6.2.2 The Sustainable Bioenergy Research Consortium (SBRC)............................................................... 48
6.3 Australian feedstock and production capacity to produce sustainable aviation fuel .......................... 49
6.3.1 Background ............................................................................................................................................ 49
6.3.2 Key stakeholders ................................................................................................................................... 50
6.3.3 Key findings – commercialisation challenges ................................................................................ 50
6.3.4 Policy environment ............................................................................................................................... 54
6.3.5 Opportunities for Australia ................................................................................................................ 54
6.4 Overview activities from SkyNRG
6.4.1 BioPort projects
6.4.2 Project Solaris
6.4.3 SkyNRG Nordic
6.5 Cathay Pacific Investment in Fulcrum Bioenergy

Glossary
Acronyms
Acknowledgements
Report on Alternative Fuels
1. Overview of biojet fuels in 2014

1.1 Chapter summary

The alternative jet fuels sector has made solid progress in 2014 with action and new initiatives in all areas. A particular highlight was the approval in June by ASTM of the third pathway to produce alternative jet fuel. Already an impressive number of flights have occurred using this fuel taking the total number of commercial airlines using alternative fuel to 21. 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.

The alternative jet fuel sector is unquestionably maturing. For many airlines the emphasis on conducting 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.

This is not to say other activity has slowed. In fact a total of 11 new multi-stakeholder initiatives have commenced in 2014 as detailed in this chapter. Further the largest off-take agreement to date was signed by Cathay Pacific amounting to one billion USD over 10 years. Despite a number of significant achievements, economics remains a challenging barrier to overcome for initial deployment. Encouragingly, efforts are intensifying to address and solve some of these commercialization conundrums and while solutions are not simple to devise the prospect for advances from the impressive work to date is encouraging.

IATA gratefully acknowledges Jane Hupe and Philippe Novelli at ICAO for their contributions to 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 aviation, with the support of the United States’ Commercial Aviation Alternative Fuels Initiative (CAAFI) and the US Air Force.

Following these milestones, initiatives 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 the hydroprocessing of vegetable oils and animal fats)

---

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.
by ASTM in September 2011 triggered the take-off of the first commercial flights using alternative fuels and, by June 2012, more than 1500 had already been flown by 17 airlines.

In the 2013 edition of this IATA report, ICAO reported on the ongoing developments and challenges on the road to large-scale deployment of alternative fuels in aviation. This contribution to the 2014 report constitutes an updated overview of the major achievements and progress made in 2014.

1.3 Technology developments

The outstanding technological achievement for 2014 is certainly the approval in June by ASTM of the third pathway to produce alternative jet fuels. This new pathway is referred to as “Synthetic Iso-paraffin” from Fermented Hydroprocessed Sugar (SIP), and was formerly known as Direct-Sugar-to-Hydrocarbon. It is a proprietary process developed by Amyris and Total, which uses advanced fermentation to convert sugars into a hydrocarbon molecule, farnesene, which can be upgraded into a jet fuel component through hydroprocessing. A paraffin is then obtained, as for HEFA and Fischer-Tropsch, with the peculiarity that it consists of one carbon chain-length only (C-15) when kerosene’s paraffins include chain-lengths from 9 to 16 carbon atoms. As a consequence, the blending ratio with fossil Jet-A1 is currently limited to 10 per cent. In the future, it is expected that engineered yeasts will be developed that produce additional carbon chain-lengths and allow for an increase in the blending ratio. The farnesene molecule is already produced at initial commercial scale in the Amyris plant of Brotas in Brazil, which can deliver 40 kt of fuel per year. Currently, the plant uses sugar cane as a feedstock, but the process can be applied to other feedstock, in particular cellulosic sugars from woody biomass and agricultural or forest residues.

The approval of additional pathways is still ongoing. These include Alcohol-to-Jet, pyrolysis and catalytic cracking (Hydroprocessed Depolymerized Cellulosic Jet), catalytic hydrothermolysis and catalytic conversion of sugars.

In 2014, Boeing also proposed to examine the possibility to use green diesel at a low blending ratio to produce aviation drop-in fuel. Unlike conventional biodiesel, which is an oxygenated compound and is unsuitable for use in aircraft, green diesel is produced from vegetable oils and animal fats via the same method as HEFA biojet fuel. Green diesel is chemically similar to HEFA, but the aviation fuel requires additional hydroprocessing to achieve the lower freezing point required for use in aircraft. This additional processing induces increased cost and a lower product yield, which is a disincentive for producers to make biojet fuel. In an initial step, blending a low ratio of green diesel, in order to comply with the jet fuel freezing point, could be a way to introduce some volume of biofuel in aviation at a lower cost.

From a longer term perspective, and with a view to the emergence of innovative technologies, it is worth noting that in 2014 the first ever “solar” jet fuel was produced, made from CO₂, water and solar energy, under the European SOLAR-JET project. The technology is currently at lab-scale, but could open the way to large-scale sustainable production of alternative fuels.

1.4 Commercial production and use of sustainable alternative fuels

The impressive number of commercial flights that were operated by airlines in the months following the approval of HEFA fuel in September 2011 should not mask the nascent character of the alternative jet fuel industry. More generally, advanced biofuels (including for example cellulosic ethanol for road transportation) are still at an early phase of development, with the first-of-the-kind plants beginning operation. Thus, commercial availability of the fuels is still limited and, in the case of aviation alternative fuels, to date, there has been no routine production of alternative jet fuel. All the commercial flights thus far were operated with specially produced batches of fuel.

However, circumstances are changing. Over the last two years, there have been signals that the regular commercial production of biojet fuel can be expected in the near future. 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 at the beginning of 2015, with a nominal production capacity of 90 kt/y of renewable diesel and jet fuel. In September 2014, the US Department of Defense...
awarded USD 210 million for the construction of three refineries that will produce military drop-in fuels. One of the recipients, Fulcrum Bioenergy, also obtained a loan guarantee from the US Department of Agriculture and entered a long term supply agreement with Cathay Pacific that made a strategic equity investment in the company. The fuel will be produced from municipal solid waste at a plant located in Nevada, which Fulcrum BioEnergy will begin construction on by the end 2014. It is anticipated that this plant will produce 30 kt of drop-in fuel from 2016, annually. A second recipient, Red Rock Biofuels, also signed an agreement with Southwest Airlines for the supply of about 10 kt of fuel per year, which will be produced from forest residues through gasification and Fischer-Tropsch synthesis. In the United Kingdom, Solena, which has concluded a partnership and purchase agreement with British Airways, has now confirmed the location of their waste-to-liquid plant, the initial production of which is expected in 2017 with 50 kt of jet fuel per year.

As mentioned, the existing Amyris/Total production plant in Brotas, Brazil, has a production capability of 40 kt/y of farnesene that can be upgraded into the newly approved SIP fuel. Moreover, Indonesia is pursuing a regulatory target to include 2% of biofuels in jet fuel by 2016 and has formed a working group to set up the production, with an agreement with the Minister of Agriculture for the supply of the feedstock.

If 2013 saw only a few commercial flights using alternative fuels, over 200 flights were operated in 2014. The Brazilian company GOL was very active in this field. GOL is working with the Brazilian Biojet Fuel Platform to achieve their target of blending 1% of biofuels in their jet fuel by 2016. GOL has achieved 200 flights with a 4% biofuel mixture during the FIFA World Cup, using 92,000 L of HEFA supplied by UOP. GOL also committed to use the newly approved SIP from Amyris/Total and achieved the first commercial flight with this fuel in September 2014. KLM continued to pursue their efforts to deploy biofuel with a new series of 20 weekly intercontinental flights from Amsterdam to Aruba, using a 20% blend of biofuels made from used cooking oil. Lastly, AirFrance have just initiated a one-year series of weekly flights between Toulouse and Paris, using a 10% blend of Amyris/Total fuel.

Figure 1 – Airlines/Fuel Producers agreements since 2009

1.5 Initiative for the development and deployment of alternative fuels

A number of collaborations from airlines and fuel producers to initiate the deployment of alternative fuels in aviation have already been mentioned. Since 2009, a total of 21 agreements between airlines and fuel producers have been recorded (Figure 1) in the Global Framework on Aviation Alternative Fuels (GFAAF), the ICAO database dedicated to alternative jet fuels. These include fuel supply agreements (e.g. United Airlines with AltAir), cooperation for technology development (the most recent example being Lufthansa with Gevo for testing of alcohol-to-Jet) or for the establishment of a production chain (e.g. British Airways with Solena), and even equity investment of airlines in fuel companies (Cathay Pacific with Fulcrum BioEnergy).

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 October 2014, 11 new multi-stakeholder initiatives and projects had been announced for 2014 (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.

Of particular note for 2014:

- 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; and
- the BIOjet Abu Dhabi initiative pursuing the setting of a supply chain in the United Arab Emirates.

Major aircraft manufacturers continue to be active in developing regional cooperation and initiatives. A MoU was signed between Airbus and Malaysian stakeholders for the creation of a centre of excellence that will assess the promising pathways for the production of alternative jet fuels in Malaysia. In the context of their cooperation announced in 2013, Boeing and South African Airways have launched their first projects to explore the potential of tobacco as an energy crop and to develop pilot programmes with small holders to produce crops for energy. In addition, Boeing is sponsoring, with the Commercial Aircraft Corporation of China (Comac), a pilot plant to produce jet fuel from gutter oils in China. Boeing also announced the creation of a joint research center with Embraer, which will carry out and coordinate biofuel research with a focus on gaps in the supply chain for sustainable aviation biofuels in Brazil.

1.6 The challenges

In 2014, the price gap with conventional jet fuels remains the first hurdle to commercial deployment of alternative jet fuels. Although fuel costs should decrease with the scale-up of production, in the short term, sustainable alternative fuels are not expected to arrive at par with fossil Jet-A1. Today, airlines are not in the position to deal with the associated premium. In addition, apart from a few exceptions, there are generally no policies in place to support the deployment of such fuels in aviation while incentives and mandates are in place for road transportation. Recent developments in biofuels policy, both in the USA and Europe, where established targets for biofuel penetration were reconsidered, have also reinforced the demand for stable and long term-oriented supporting policies.

An additional challenge is to complete the development of the technologies, which are not all yet mature, and to bring them to market. 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 critical financial situation 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.

Ensuring sustainable deployment is also a core challenge for the aviation industry. This includes not only achieving life cycle GHG emissions reductions, but also compliance with the environmental, societal and economic pillars of sustainability as recognized by ICAO Resolution A38-18 on Aviation and Climate Change. In that domain, it is notable that a number of actors are in the process or have already achieved environmental certification, as is the case for Amyris, LanzaTech and SkyNRG with the RSB standard. However, as pointed out by ICAO SUSTAF experts group in 2013, not all the impacts of deploying alternative fuels can be measured at the individual production-chain level and there is a need for States’ policy and monitoring to address sustainability at a more global level, including in decision-making. Due to the global nature of international aviation, sustainability is certainly a topic for which increased harmonization and collaboration between countries would yield benefit to facilitate the deployment of alternative fuels.

A significant challenge today regarding sustainability is the assessment of the indirect impacts of a large scale deployment of alternative fuels. Indirect land use change (ILUC) and impacts on food security have raised a number of discussions over the past year. The assessment and management of these impacts is currently not fully mature and require additional methodological work and increased cooperation.

5. Round table for Sustainable Bioenergy.

6. ILUC is the land-use change induced in a different geographic area by the deployment of energy crops in one locale which leads to the displacement of previously existing crops. It is not directly observable and is recognized to potentially create GHG emissions.
In 2014, the price gap with conventional jet fuels remains the first hurdle to commercial deployment of alternative jet fuels. Although fuel costs should decrease with the scale-up of production, in the short term, sustainable alternative fuels are not expected to arrive at par with fossil Jet-A1. Today, airlines are not in the position to deal with the associated premium.

In addition, apart from a few exceptions, there are generally no policy in place to support the production of sustainable aviation biofuels. The lack of policy frameworks and incentives hinders the widespread adoption of these fuels.

**Figure 2** – multi-stakeholders initiatives announcements (Synthesis of GAAF database as per October 2014)

**Figure 3** – mapping of worldwide initiatives (based on announcements recorded in GAAF – *Non meant to be exhaustive – mainly initiatives since 2013*)
deployment of such fuels in aviation while incentive and mandates are in place for road transportation. Recent developments in biofuels policy, both in the USA and Europe, where established targets for biofuel penetration were reconsidered, have also reinforced the demand for stable and long term-oriented supporting policies.

An additional challenge is to complete the development of the technologies, which are not all yet mature, and to bring them to market. 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 critical financial situation 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 key to making sufficient volumes of sustainable feedstock available for long term, large-scale deployment. This includes increasing yields and developing innovative feedstock, such as algae.

Ensuring sustainable deployment is also a core challenge for the aviation industry. This includes not only achieving life cycle GHG emissions reductions, but also compliance with the United Nations Sustainable Energy for All (SE4ALL) initiative of the United Nations.

1.7 Achievements under ICAO

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 deploy alternative fuels in aviation, through fostering exchanges, sharing information and promoting further common work under ICAO.

In particular, ICAO maintains and develops the GFAAF, a web platform through which a unique database on aviation alternative fuels developments is made available to the aviation community. This includes up-to-date news and announcements, as well as descriptions of ongoing initiatives, reference documentation and educational material. The GFAAF is a reference for ICAO Member States and for interested stakeholders who want to be informed on alternative fuels development and was proposed as the unifying tool for the aviation community within the SE4ALL initiative of the United Nations.

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 fuels.
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. Additional detail is presented in Chapter 2.

On 23 September 2014, the UN Secretary-General, Mr. Ban Ki-moon, invited Heads of State and Government, along with business, finance, civil society and local leaders to the UN Climate Summit, held in New York. ICAO was invited to participate jointly with the Air Transport Action Group (ATAG) in the Summit as a prime example of a long-standing, successful partnership with the aviation industry to progress shared environmental objectives. The President of the ICAO Council delivered a joint action statement by ICAO and ATAG on the partnership between governments and the aviation industry on actions to reduce aviation CO₂ emissions, including supporting the development of sustainable alternative fuels for aviation.

1.8 Conclusion

There is a long way before a new industry emerges and reaches a significant market penetration. 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. Stakeholders all over the world are now pushing for the next step, and initiatives continue to multiply in an increasing number of countries, to set up production or assess the feasibility of such production. The first regular commercial production should take off by 2015, though still at a limited scale.

Economics is the prominent barrier to overcome for initial deployment, which needs to be articulated with environmental goals and policies, as, during the preliminary phase, reducing environmental impacts may not be without cost. Long term perspectives and industry time scales should be included in the equation as aviation has limited expectation to move away from liquid fuel in the short to mid-term. Stabilizing aviation GHG emissions in spite of the impressive forecasted growth of air traffic requires developing alternative fuels and associated technologies from now.

The issue is certainly complex, especially from the point of view of the availability of sustainable resources, when considering the production levels required for achieving the aspirational goals. In that sense, progressing together with a better understanding and shared evaluation of the potential for future emissions reduction is a cornerstone to informed decision-making. The work being undertaken by ICAO, and within CAEP by the Alternative Fuels Task Force is a key contribution to this effort, that will also need an increased cooperation with the other stakeholders from the bioenergy sector.
2. Standard harmonisation and a future market based mechanism

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 provides some 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

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.

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 ICAO’s work post Assembly
In Resolution A38-18, the Assembly requested that the ICAO Council finalize the work on the possible options for a global MBM scheme. The results of the Council’s work are to be presented, for decision, at the 39th Session of the Assembly in 2016.

In order to advance the work, the ICAO Council set up an ad hoc group, the Environment Advisory Group (EAG). At the request of the EAG, ICAO’s Committee for Aviation Environmental Protection (CAEP) also established the Global MBM Technical Task Force (GMTF). While the EAG focuses on the political aspects of a global MBM, the GMTF is dedicated to technical questions and analysis in support of discussions in EAG.

A prime focus of EAG is to ensure the design of a global market-based measure adequately takes into account the different situations of ICAO Member States and maturity of the various air transport markets without distorting competition between airlines. As for GMTF, its remit includes the development of proposals for the monitoring, reporting and verification of emissions, as well as recommending eligibility criteria for emission units under the global MBM.
Without any doubt, alternative fuels will play a very important role in the context of a future global MBM and Aircraft operators should be appropriately credited for the greenhouse gas emissions reductions achieved through the use of sustainable alternative fuels in aviation. Consequently, the monitoring and reporting of these fuels is within the scope of GMTF which, in this task, will benefit from the support and expertise of CAEP’s Alternative Fuels Task Force (AFTF).

IATA is naturally actively engaged in the work of ICAO on a global MBM, with the firm aim of States signing off on an agreed global MBM for application from 2020.

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 Biofuels (now Biomaterials, RSB) 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 Alternative Fuels Report.

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 that are not directly comparable with each other. Therefore it will be a challenging task to define a preferred set of sustainability criteria that have a chance to be accepted at ICAO level, i.e. by 191 states.

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

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

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 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.

<table>
<thead>
<tr>
<th>Sustainability criteria</th>
<th>National legislations</th>
<th>Voluntary schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RED</td>
<td>RFS2</td>
</tr>
<tr>
<td>Economic criteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social criteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil, air &amp; water protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land conversion restrictions - biodiversity &amp; carbon stock protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG savings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

2.3.4 Two potential approaches

Two possible, and complementary, ways to approach this task are:

- Mutual recognition between the most important regulatory standards, namely the EU RED and the US RFS. To support this, comparative analyses would be helpful, such as between the lifecycle emissions of the most common biojet fuel pathways according to both methods. The need to find a solution at ICAO would be an excellent catalyst for negotiations between the EU and the US. Additionally, mutual recognition of the standards in both jurisdictions would help biofuel producers export their products into different world regions without the burden of multiple certification.

- Defining a “meta-standard” or framework that different national standards would have to meet; 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 level defining the requirements for recognition under the ICAO global MBM, higher (“silver” and “gold”) levels could be established for additional voluntary certification of producers and/or operators.

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, as currently planned e.g. for Amsterdam, Oslo and Brisbane airports. 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)9.

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 4 – Different chain of custody approaches](image)

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.

IATA has worked with the consultancy company Ecofys to elaborate viable options for harmonization of sustainability standards and biofuel accounting rules. The results from this investigation will be made available for consideration in the upcoming development of the ICAO global MBM.
3. Sustainability

3.1 Chapter summary
As highlighted in Chapter 2, different sustainability standards are in use for aviation biofuels, both regulatory and voluntary. A selection of the most relevant standards is 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. Despite this, the International Sustainability and Carbon Certification (ISCC) is the most widely-used of the voluntary certification schemes that are recognized under the European Renewable Energy Directive (RED). This chapter highlights some of the activities of RSB and IATA gratefully acknowledges Rolf Hogan at RSB for the contribution to this chapter.

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

Following developments in land transport, biofuels became a promising choice of a sustainable alternative energy for aviation because of their reduced net carbon dioxide emissions compared to fossil fuels. For aviation there are no other sustainable alternative energies available in the near-to-mid-term, contrary to the automotive sector which already offers solutions using electric batteries and fuel cells. It is however essential that, in addition to greenhouse gas savings, other environmental, societal and economic aspects of sustainability 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
2014 has been a very important year for RSB. The active engagement of RSB with industry leaders has led to a growth in certification, including several companies who supply biojet fuel to the aviation industry. RSB was rated the best biofuels sustainability certification in three separate reports from WWF (World Wide Fund For Nature), International Union for Conservation of Nature (IUCN), and NRDC (Natural Resources Defense Council).

Improvements to the standard and procedures have also made the RSB certification system more user-friendly. In September 2014, RSB’s Assembly of Delegates approved a new smallholder standard which aims to provide small producers with additional flexibility in the compliance process through a stepwise approach and the waiving of certain certification requirements. The smallholder standard arose from work within RSB’s Smallholder Program, which was launched in late 2013 and seeks to improve the livelihoods of small farmers by linking them to markets and promoting sustainable practices based on the RSB standard.
While RSB’s market share remains relatively small, the RSB standard is clearly appealing to industry players that want to promote their positive performance, and to achieve RSB’s robust certification, that effectively covers social, environmental and financial aspects of sustainability. During 2015, RSB will focus on expanding smallholder initiatives and access to certification, further streamlining the applicability of the standard to any bio-based feedstock, and strengthening its position as the highest rated biofuels sustainability certification in the world.

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

3.3.1 Smallholders Initiative

The RSB Smallholder program launched in December 2013 with the help of The Boeing Corporate Citizenship program and the Swiss State Secretariat for Economic Affairs (SECO) to support small farmers in Southern Africa and Latin America. The program seeks to improve the livelihoods of small farmers by linking them to markets and promoting sustainable practices using RSB certification.

In 2014, Boeing and RSB are working with South African Airways (SAA) and other stakeholders to create pilot programs to build knowledge and skills among groups of farmers who want to certify their crops as sustainable. SkyNRG, which is RSB certified, announced its first major feedstock project in South Africa based on the Solaris technology. Solaris is a nicotine-free energy tobacco crop that’s developed by the Italian company Sunchem. SkyNRG and Sunchem SA have teamed up to roll out Solaris in Southern Africa at large scale to help power local sustainable jet fuel production. Solaris aims to demonstrate its sustainability by meeting RSB’s criteria. Boeing, SAA, SkyNRG and the RSB are already working together with Southern African stakeholders to position farmers with small plots of land to tap markets for biofuel feedstocks that provide socio-economic value to communities without harming food supplies, fresh water or land use. Soon we will see the benefits of certification, as smallholders improve their livelihoods through sustainable feedstock production.

RSB also developed an adaption of the RSB Standard and certification process for smallholder groups. The adapted standard aims to provide small producers with additional flexibility in the compliance process through a stepwise approach and the waiving of certain requirements. Draft documents were developed by EPFL in partnership with AidEnvironment and the Swiss Agency for Development and Cooperation (SDC), and reviewed by the RSB Secretariat. A public consultation period was conducted to collect additional feedback and suggestions and the final smallholder standard was approved by the RSB Assembly of Delegates at the 2nd RSB General Assembly held in São Paulo on September 23, 2014.
3.3.2 Brazil Biofuels Platform

RSB continues to support sustainability initiatives in the Brazilian aviation sector. In 2014, RSB participated actively in meetings and events of the Brazilian Biofuels Platform, as in the first GOL Airlines commercial flight departing from Belo Horizonte airport using biojet fuel. With other partners, RSB signed a MoU with the Minas Gerais State government to support the development of biojet fuel production in the state, which is studying the use of macauba palm tree oil (extracted from its fruits) as a regional feedstock. Currently, RSB is also discussing collaboration with the Rio Grande do Sul state to assist the biojet fuel initiative in South Brazil.

In May 2014, Amyris earned RSB certification for its plant in Brotas, São Paulo, Brazil. The Amyris biorefinery in Brotas produces farnesene from sugar cane feedstock. Farnesene serves as precursor in many applications, including biojet fuel production. RSB and Amyris are working to have certified products available to the biojet fuel market soon.

3.3.3 Sustainable Aviation Fuel User Group (SAFUG)

SAFUG, an alliance of 24 international airlines, has pledged to preference RSB-certified biofuel. In addition, roadmaps for sustainable aviation biofuel in Australia/New Zealand, Brazil, Mexico and the United States of America have called for sustainable biofuel based on RSB principles.

3.3.4 Sustainable Aviation’s “Fuelling the Future”

Sustainable Aviation published “Fuelling the Future” in 2014 which notes support of RSB as the most robust global sustainability standard saying “In pursuing high volume production of these new fuels, SA members remain committed to the highest possible sustainability standards, ensuring that the raw materials and processes used have minimal impacts on direct and indirect land use, do not compete with food or water supplies, result in substantial life cycle carbon reductions and are independently certified to the highest sustainability standards, such as the Roundtable on Sustainable Biomaterials (RSB).” Read more here.
3.3.5 Airbus and Virgin Australia Study

A two-year study commissioned by Airbus and partners including Virgin Australia in 2012 into the practicability of using Australia’s mallee trees to make biofuels suitable for powering passenger jets has reported encouraging results. The report published by the Future Farm Industries Cooperative Centre (CRC) concludes that jet fuel made from the mallee tree will meet strict sustainability criteria determined by the RSB and will be suitable for commercial flights according to the American Society for Testing and Materials (ASTM). Read full article.

3.3.6 RSB Rated Best Biofuels Sustainability Certification Worldwide

Over the past year, independent analyses conducted by numerous international organizations, including NRDC, WWF and IUCN, confirm that RSB is the best performing biofuels sustainability certification program in the world. WWF summarizes:

“WWF International, IUCN NL and most recently NRDC assessed biofuels certification schemes either against each other, or against a set of criteria. Despite different methodologies and varying numbers and set of standard schemes examined, their findings largely concur and all find RSB to be the strongest, most robust scheme.”

“The most comprehensive and ambitious of the recognized schemes is the RSB. The RSB’s principles and criteria include avoiding negative impacts on biodiversity and ecosystems, reducing greenhouse-gas emissions by at least 50%, maintaining water resources, improving food security, and contributing to social and economic development.”

Read more on WWF’s website.

3.3.7 SSI Report States RSB Only Initiative Demonstrating 100% Coverage of All Three SSI Greenhouse Gas Indicators

The latest “State of Sustainability Initiatives Review 2014: Standards and the Green Economy” report indicates that the RSB is the only initiative demonstrating 100 per cent coverage of all three SSI greenhouse gas indicators. The State of Sustainability Initiatives (SSI) project is facilitated by the Sustainable Commodity Initiative and has been directly managed by the International Institute for Environment and Development (IIE), the International Institute for Sustainable Development (IISD), the Finance Alliance for Sustainable Trade, Environment and Trade in a World of Interdependence (ENTWINED), and the Sustainable Trade Initiative (IDH). Download the full SSI report here.

3.3.8 Streamlining and Improvement of RSB Standard Continues

RSB continuous to streamline and improve the standards and certification system to make it simpler, more accessible, business-friendly and cost effective. Requirements and compliance evaluation have been made simpler and less burdensome while preserving their robustness and the comprehensive addressing of sustainability, traceability and assurance issues. In 2014, several documents were developed or revised, including documents related to Operators taking part in the RSB Certification, Communication and Claims, Risk Management, and Traceability of RSB Certified Material. The RSB Secretariat is currently revising all the requirements related to the qualification of auditors, certification bodies and the conduction of audits, with an expected approval by the RSB Board of Directors by the end of 2014.

In 2015, the RSB will hold several rounds of member and public consultation on the revised Principles & Criteria (RSB-STD-01-001), which describe the environmental, social and economic requirements economic operators shall comply with in order to receive RSB certification.

Finally, the RSB Secretariat is currently working on the development of compliance indicators based on the “Low Indirect Impact Biofuels” (LIIB) methodology. First certifications based on LIIB are expected in 2015.
4. Economics

4.1 Chapter summary

It is widely accepted that the largest impediment for Biojet fuel is not a technological constraint but rather economics and policy.

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

The ‘valley of death’ is often referenced when describing the challenges of achieving commercialisation of the technical potential that currently exists for sustainable alternative fuels. This typically implies a scarcity of capital, both equity and debt at funding rates congruent with achieving a commercial business case.

IATA gratefully acknowledges Mitch R. Withers, Matthew N. Pearlson, and Robert Malina of M.I.T. for their contributions to this chapter.

4.2 Conventional jet fuel price development and incentives for alternative fuels as points of reference

Alternative aviation fuels compete with conventional jet fuel from petroleum. Airlines operate in a highly competitive, low-margin market and can be expected to refrain from large-scale usage of alternative fuels if they are not cost-competitive with the conventional counterpart. This does not necessarily imply that these fuels need to be competitive on their own in the short term, since there are policies in place that give incentives to produce and use alternative aviation fuels.

One example is the revised Renewable Fuels Standard (RFS2) described in Chapter 3 of this report. Although the renewable volume obligations (RVO) specified by RFS2 do not require production of renewable jet fuel, it can qualify for a renewable identification number (RIN)[1], which can be traded and used by obligated parties to satisfy renewable fuel mandates. At current prices, RINs can offset the cost differential between alternative and conventional jet fuel by $0.26/L ($1/gal). However, because separating jet fuel from diesel fuel requires additional processing, RFS2 is more likely to incentivize biomass-based diesel production over biojet[2].

While there is considerable uncertainty about the future price of conventional jet fuel, prices are generally expected to increase in the coming decades due to increased global demand for crude. The U.S. Energy Information Administration has published past and current jet fuel prices in the United States as well as price projections for jet fuel for the next three decades (see Figure 4)[3]. As shown in the figure, baseline EIA projections suggest that the price of jet fuel will increase over the next thirty years. In the high price scenario jet fuel sells at around ($5/gal in 2040, (in 2012 U.S. dollars), in the low scenario it sells at around $2/gal. The average U.S. spot price of jet fuel for 2013 was $3.05/gal, while November 2014 spot prices were around $2.25/gal).
4.2.1 Actual purchase prices

Alternative jet fuels are currently produced in small quantities compared to both petroleum jet and corn ethanol: From 2007 to 2012, the U.S. military has purchased 1.9 million gallons of jet fuel through its procurement agency DLA Energy, which gives reliable data regarding the actual purchase prices of biofuels. These are shown in Table 1.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Quantity in L (gal)</th>
<th>Total Cost ($/gal)</th>
<th>Average Cost $/L ($/gal)</th>
<th>Min $/L ($/gal)</th>
<th>Max $/L ($/gal)</th>
<th>Contracts (Suppliers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRJ/HEFA⁸</td>
<td>4,108,428 (1,085,450)</td>
<td>$41,534,620</td>
<td>10.11 (38.26)</td>
<td>7.07 (26.75)</td>
<td>39.37 (149.00)</td>
<td>12 (4)</td>
</tr>
<tr>
<td>FT⁹</td>
<td>2,763,050 (730,000)</td>
<td>$2,745,650</td>
<td>0.99 (3.76)</td>
<td>0.90 (3.41)</td>
<td>1.85 (7.00)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>ATJ¹⁰</td>
<td>352,005 (93,000)</td>
<td>$5,487,000</td>
<td>15.59 (59.00)</td>
<td>15.59 (59.00)</td>
<td>15.59 (59.00)</td>
<td>4 (1)</td>
</tr>
<tr>
<td>DSH¹¹</td>
<td>162,755 (43,000)</td>
<td>$1,106,390</td>
<td>6.80 (25.73)</td>
<td>6.80 (25.73)</td>
<td>6.80 (25.73)</td>
<td>4 (1)</td>
</tr>
<tr>
<td>HDC-D¹²</td>
<td>24,603 (6,500)</td>
<td>$57,525</td>
<td>2.34 (8.85)</td>
<td>2.34 (8.85)</td>
<td>2.34 (8.85)</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>

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

HRJ/HEFA fuels are produced by hydroprocessing esters and fatty acids, such as edible (soybean, canola) and non-edible (camelina, jatropha) plant oils, algal oil, yellow grease (rendered used cooking oil), and tallow (rendered animal fat). The maximum price of $149/gal corresponds to fuel produced from algal oil, the economics of which have been discussed in previous editions of this report⁹. Between 2007 and 2012, the U.S. military procured 1 million gallons of HRJ/HEFA jet fuel at an average price of $10.04/L ($38/gal).

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

8. Hydroprocessed Renewable Jet/Hydroprocessed Esters and Fatty Acids from camelina, algal oil, used cooking oil, tallow
10. Alcohol to Jet from alcohols
11. Direct Sugar to Hydrocarbon from sugar fermentation
12. Hydrotreated Depolymerized Cellulosic Diesel from lignocellulosic biomass
Alcohol-to-jet (ATJ) processes use commodity alcohols (ethanol, butanol) as platform molecules for oligomerization or catalytic synthesis reactions. Alcohols can also be produced from biomass via advanced fermentation processes. So far, less than 378,500 L (100,000 gal) of ATJ were purchased by the U.S military from a single supplier at a price of $15.59/L ($59/gal).

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

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

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

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

In September 2014, Southwest Airlines announced purchase of 3 million gallons of jet fuel p.a. from woody biomass using a Fischer-Tropsch process at a price of around $3 USD per gallon from Red Rock Biofuels. Red Rock Biofuels received a $70 million grant from the U.S. government for building a biorefinery in Oregon. Delivery of the fuel is expected to start in 2016.

In April 2014, British Airways announced procurement of 16 Million gallons of jet fuel p.a. at prices competitive to conventional jet fuel from Solena, a company using municipal solid waste and F-T technology to produce jet fuel.

4.2.2 Theoretical purchase prices

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

Theoretical purchase prices for mature industries have been calculated in literature using minimum selling price (MSP) approaches. These prices are meant to be representative for fuels which are produced in several refineries using a certain technology, with lower contingency, start-up costs and risk premiums than first of its kind plants. These “N-th plant” studies rely on technoeconomic analyses to estimate capital expenses and operating costs for fuel production facilities. Plant economics can be assessed by employing a discounted cash flow rate of return (DCFROR) model, which is standard practice for chemical engineering cost analysis. These models capture the net present value of discounted cash flows related to loan interest payments, direct and variable operating costs, sales revenues, and taxes. Other financial parameters are included as necessary, such as construction time, production ramp up, depreciation, and inflation to model various production scenarios. The minimum selling price is determined from this information and represents the price at which the fuel must be sold in order for the project to achieve a specified internal rate of return (with a net present value of zero). If multiple products are produced, the prices of the co-products are either held constant at market value (isolated cost burden) or varied relative to the jet fuel price (distributed cost burden).
Table 2 gives price estimates for HRJ/HEFA, FT, and ATJ fuel pathways. Price estimates are based on current technologies, and major technological advancements are not factored in. The MSP is a plant gate price and excludes transport, taxes, and retail markup. Baseline scenarios reflect average efficiencies and intermediate plant sizes, while low and high scenarios are determined by varying feedstock costs, plant sizes, efficiencies, and capital expenses within reasonable bounds. The estimates show that HRJ/HEFA, FT jet from biomass and ATJ fuels are expected to significantly decrease in cost compared to prices currently being paid. Current coal and natural gas FT purchase prices are close to the estimated MSPs already due to the maturity of FT technology. Based on N-th plant estimates, all fuels considered can potentially become cost competitive to conventional jet fuel.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Feedstock</th>
<th>Minimum selling price estimate (MSP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low ($/L)</td>
</tr>
<tr>
<td>HRJ/HEFA</td>
<td>Soybean oil</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>Tallow</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Yellow grease</td>
<td>0.88</td>
</tr>
<tr>
<td>FT</td>
<td>Natural gas</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Coal</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>Switchgrass</td>
<td>1.42</td>
</tr>
<tr>
<td>ATJ</td>
<td>Sugar cane</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Corn grain</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Switchgrass</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Table 2 – Theoretical fuel prices for alternative jet fuels from different feedstocks and pathways.
Sources: Ref. 8, 10,13 and ongoing MIT research.

4.2.3 Cost drivers

HRJ/HEFA fuel prices are driven by high feedstock costs. The feedstocks shown in Table 2 (soybean oil, tallow, and yellow grease) are often more expensive in their raw forms than conventional jet fuel. Soybean oil is more expensive but more readily available than tallow or used cooking oil, which are available only in small quantities, limiting the scalability of commercial production. Using USDA data on feedstock availability it can be shown that up to 500 million gallons of HEFA jet fuel, 240 million gallons of HEFA diesel and 80 million gallons of naphtha could be produced annually if all tallow and yellow grease rendered in the US were used. This would account for ~3% of current jet fuel demand in the US.

It is well understood that capital expenses are the main drivers for Fischer-Tropsch synthesis[9]. Specifically, the gasifier, air separation unit, and FT reactor are the most expensive components. One advantage of FT synthesis is its ability to use syngas derived from a variety of inexpensive feedstocks.
ATJ pathways have higher relative capital costs than HEFA fuel pathways, but still lower than FT. However, the sugar-yielding feedstocks considered are less expensive than oily feedstocks, especially in the case of sugars derived from lignocellulosic biomass such as switchgrass.

4.2.4 Future cost reductions

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

As has been shown above, feedstock costs play a critical role for the economics of biofuels, especially in the case of HEFA jet fuel. Waste oils and animal fats are cheaper feedstocks that lead to relatively lower fuel prices but are limited in availability. Alternative low-cost feedstocks for HEFA processes include oilseed crops grown in rotation with other crops on land that otherwise would have been left fallow, thereby increasing the efficiency of land use. Two promising rotation crops in the US include pennycress and camelina. As long as oilseed rotation crops do not impact pest
control, moisture, and nutrient content of the soil in comparison to fallow land, there are no opportunity costs associated with using this land for these crops. Costs are only incurred during the actual cultivation. In a recent study, Winchester et al. (2013) estimate that HEFA jet fuel from rotation crops in the U.S. such as camelina and pennycress could be produced at around $0.98/L ($3.70/gal)[2]. This paper also states that these rotation crops could potentially be grown on ~43 million acres in the U.S. per year, which could yield up to 12.1 billion L (3.2 billion gal) of renewable jet fuel per year.

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

4.3 Valley of Death Economics: Sustainable Aviation Fuel

4.3.1 Introduction
In the last decade, the prospect of using sustainable alternative fuel in commercial aircraft has become a reality. Currently three alternative fuel fuel production pathways have been approved by standards agency ASTM International and over 1600 commercial flights have occurred by 21 different airlines. These ‘drop-in fuels’ are certified as chemically equivalent to fossil derived fuel and are totally fungible with existing fuel delivery infrastructure at airports.

Demand for aviation is growing strongly: aviation has carried around 65 billion passengers over the last 100 years, but the next 65 billion will take flight by 2030. There are considerable benefits of this growth in connectivity, however, it also has an environmental consequence. Aviation is responsible for around 2% of man-made carbon emissions and the industry accepts its responsibility to reduce emissions sustainably if it is to have a future ‘license to grow’.

Consequently, aviation is the only global industry with clear targets and a comprehensive strategy to reduce emissions. In 2009 airlines made a commitment to carbon neutral growth as part of a set of three sequential goals for air transport:

≋ Improve fuel efficiency by 1.5% annually to 2020
≋ Cap net emissions from 2020 with carbon-neutral growth (CNG2020)
≋ Cut net emissions in half by 2050 compared to 2005.

While the technological progress has been remarkable the actual uptake of sustainable alternative fuel has been modest due to these fuels still being produced in relative small quantities. Without economies of scale the unit cost of production remains, in general, higher than traditional fossil derived kerosene and this price impediment is limiting the wider spread use.

In economics, we refer to this problem as the ‘valley of death’ or in simple language, a funding gap. What this implies is that a roadblock exists in the commercialization sequence. Substantial capital is required to develop biojet fuel refining and process capacity, and often projects that are capable of generating socially desirable commercial products are unable to obtain financing.
Addressing the valley of death conundrum should be a priority for policy makers that have the available tools and mechanisms to enable progress in this new industry.

4.3.2 About the “Valley of Death”

Transitioning from fossil derived aviation fuel to a low carbon aviation fuel requires cutting edge, lower cost generation technologies. This is occurring with numerous different pathways successfully demonstrating technological capability, however most are yet to achieve commercial penetration. To achieve environmental objectives such as carbon neutral growth and a halving of CO₂ emissions by 2050 relative to the 2005 baseline, this scientific potential must move quickly from the lab to widespread deployment. Moving a technology from the research to the commercial phase can be extremely challenging. It requires traversing the so called ‘valley of death’. This phrase intends to describe the convergence of high cash demand such as that required for a refinery and a scarcity of capital. Building a small scale demonstration facility may require a fraction of the capital required to develop a commercial scale facility. Furthermore, even if a demonstration scale facility performs as expected, it does not render riskless the transformation from small scale to commercial scale. This risk premium applied to the cost of capital can mean achieving a positive benefit-cost business case is difficult.

Figure 6 – Source: Osawa and Miyazaki.
Without the right policy framework, projects that are capable of generating socially desirable commercial products or processes are unable to obtain financing at the intermediate stage of the innovation sequence. Some of the ‘valley of death’ impediments include:

1. **Construction** – what is the cost and time to complete?
2. **Technology** – what if the technology does not work at industrial scale, or fails to yield the promised production?
3. **Feedstock** – will it be available at any cost, let alone at the presumed cost?
4. **Policy** – if the project’s viability depends on government policy assistance, will that policy remain constant throughout the facility’s economic life?
5. **Financial** – have the economic assumptions such as the cost of debt and equity, cost of production, selling price of all of the fuel products been realized?
6. **Engineering** – is the engineering and design of the plant appropriate?
7. **Management** – what experience does management have and what happens if it proves inadequate for the task?

This can seem like a daunting list, however, it is possible to either minimize or eliminate a number of these risks. While the appetite to invest equity in this sector will likely remain situational, reducing these risks has the potential to unlock the necessary debt and private equity capital required to develop production capacity. Recent evidence suggests that when all stakeholders including policy makers address these issues, positive financial agreements can be achieved. Examples include British Airways and Cathay Pacific, both committing to significant off-take agreements and also taking an equity position in the technology.13

Financial examples:

The below five examples are designed to be a simple demonstration, that achieving a positive Net Present Value business case can be sensitive to many small changes in the input assumptions. Further, they highlight how policy can be effectively applied to influence a projects financial viability. While a ‘real life’ project will have numerous line items within construction, operating costs and revenues, for the sake of simplicity these are aggregated. All the examples are hypothetical, illustrative and should be of interest to policy makers.

**Example 1:**

Example 1 is a base case scenario. This is an example where purchasing land, equipment and constructing a biojet refining plant cost $260 million. Both operating costs and revenues ramp up, then remain consistent from year 3. In a real world scenario these are not likely to be linear but this does not impact the example. A discount rate of 9% is assumed. This example delivers a forecast NPV of -$83.28 million or an internal rate of return on the funds employed of 3.82%. A rational firm would not undertake this project.

<table>
<thead>
<tr>
<th>EXAMPLE: 1</th>
<th>Simplified cost-benefit example - base case project CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project analysis (Million USD)</td>
<td></td>
</tr>
<tr>
<td><strong>Year</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Capital costs</strong></td>
<td></td>
</tr>
<tr>
<td>Project construction</td>
<td>-250</td>
</tr>
<tr>
<td>Improvements</td>
<td>-10</td>
</tr>
<tr>
<td>Equipment</td>
<td>-10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-260</td>
</tr>
<tr>
<td><strong>Operating costs</strong></td>
<td></td>
</tr>
<tr>
<td>Aggregate annual costs</td>
<td>-5</td>
</tr>
<tr>
<td><strong>Net Cash Flow</strong></td>
<td>-260</td>
</tr>
<tr>
<td><strong>Discount rate</strong></td>
<td>9%</td>
</tr>
<tr>
<td><strong>NPV</strong></td>
<td>-$83.28</td>
</tr>
<tr>
<td><strong>IRR</strong></td>
<td>3.82%</td>
</tr>
</tbody>
</table>

13. Refer to the IATA biojet fuel roadmap document under Policy / Economics and Financing strategies
Example 2:
Example 2 replicates example 1, except in this case a project grant of $100 million is received. This could be a government grant. Interestingly, in 2014 the US Department of Defense awarded $210 million under the Defense Production Act to Emerald Biofuels, Fulcrum and Red Rock Bio towards the construction of bio-refineries that produce cost-competitive, drop-in military biofuels. A grant is often contingent on satisfying certain criteria, however, in this case it is assumed this criterion is met and the funds are received unconditional.

While the aggregate of the grant is only 2.5 years of projected revenue, the advantage of receiving these funds at project inception is significant, particular with a high discount rate.

This change to the project delivers a $16.72 million positive NPV at an IRR of 10.43%. A rational firm would undertake this project.

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project construction</td>
<td>-250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project grant</td>
<td>100</td>
<td>187.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvements</td>
<td>-10</td>
<td>-25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td>-10</td>
<td>17.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-160</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate annual costs</td>
<td>-5</td>
<td>-15</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>Revenues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual aggregate revenues</td>
<td>15</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>-160</td>
<td>-15</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>230</td>
</tr>
<tr>
<td>Discount rate</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV</td>
<td>$16.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>10.43%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example 3:
Example 3 replicates example 1 except in this case the firm acquires an interest free loan for 10 years of $100 million. This could be provided from a government program and when the project is more mature this debt could easily be refinanced and repaid. Further, conceptually the idea of an interest free loan could be substituted with non-dilutive equity.

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project construction</td>
<td>-250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest free loan</td>
<td>100</td>
<td>187.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvements</td>
<td>-10</td>
<td>-25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td>-10</td>
<td>17.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-160</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-35</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate annual costs</td>
<td>-5</td>
<td>-15</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
</tr>
<tr>
<td>Revenues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual aggregate revenues</td>
<td>15</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>-160</td>
<td>-15</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>130</td>
</tr>
<tr>
<td>Discount rate</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV</td>
<td>$25.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>6.37%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While the project NPV remains negative at -$25.52 million it is substantially improved on example 1. Further, the IRR of 6.37% may be feasible for some investors.
Example 4:
Example 4 replicates example 1 however in this case the biojet supplier receives a subsidy. While in this case the subsidy is not sufficient to generate a positive project NPV it demonstrates the annual subsidy improves the forecast IRR from 3.82% in example 1 to 5.23% in example 4.

<table>
<thead>
<tr>
<th>Example 4</th>
<th>Simplified cost-benefit example - revenue subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
</tr>
<tr>
<td>Project construction</td>
<td>-250 187.5</td>
</tr>
<tr>
<td>Improvements</td>
<td>-20 17.5</td>
</tr>
<tr>
<td>Equipment</td>
<td>-10 5</td>
</tr>
<tr>
<td>Total</td>
<td>-260 210</td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
</tr>
<tr>
<td>Aggregate annual costs</td>
<td>-15 -20 -20 -20 -20 -20 -20 -20 -20 -20 -20</td>
</tr>
<tr>
<td>Revenues</td>
<td></td>
</tr>
<tr>
<td>Subsidy</td>
<td>1.5 2.5 4 4 4 4 4 4 4 4 4</td>
</tr>
<tr>
<td>Annual aggregate revenues</td>
<td>15 25 40 40 40 40 40 40 40 40 40</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>-260 11.5 12.5 24 24 24 24 24 24 24 24 234</td>
</tr>
<tr>
<td>Discount rate</td>
<td>9%</td>
</tr>
<tr>
<td>NPV</td>
<td>-$81.76</td>
</tr>
<tr>
<td>IRR</td>
<td>5.23%</td>
</tr>
</tbody>
</table>

Example 5:
Example 5 incorporates some of the policy features of the other examples. It includes a revenue subsidy of 10% of revenues, a project grant of $50 million and an interest free loan of $100 million repayable in 10 years.

This example clearly demonstrates how combining some policy mechanisms can make an otherwise unattractive project successful. Example 5 generates a forecast NPV of $46.59 million at an IRR of 15.1%. Even at a discount rate of 9% this project is comfortably acceptable. This demonstrates how connected stakeholders such as the project owner and operator, the government, product demand e.g. an airline and debt financiers work collaboratively, policy mechanisms can combine to build a strong business case.

<table>
<thead>
<tr>
<th>Example 5</th>
<th>Simplified cost-benefit example - project grant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>Capital costs</td>
<td></td>
</tr>
<tr>
<td>Project construction</td>
<td>-250 187.5</td>
</tr>
<tr>
<td>Project grant</td>
<td>50 0</td>
</tr>
<tr>
<td>Interest free loan</td>
<td>100 -100</td>
</tr>
<tr>
<td>Improvements</td>
<td>10 17.5</td>
</tr>
<tr>
<td>Equipment</td>
<td>-10 5</td>
</tr>
<tr>
<td>Total</td>
<td>-110 110</td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
</tr>
<tr>
<td>Aggregate annual costs</td>
<td>-15 -20 -20 -20 -20 -20 -20 -20 -20 -20 -20</td>
</tr>
<tr>
<td>Revenues</td>
<td></td>
</tr>
<tr>
<td>Subsidy</td>
<td>1.5 2.5 4 4 4 4 4 4 4 4 4</td>
</tr>
<tr>
<td>Annual aggregate revenues</td>
<td>15 25 40 40 40 40 40 40 40 40 40</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>-110 11.5 12.5 24 24 24 24 24 24 24 24 135</td>
</tr>
<tr>
<td>Discount rate</td>
<td>9%</td>
</tr>
<tr>
<td>NPV</td>
<td>$46.59</td>
</tr>
<tr>
<td>IRR</td>
<td>15.1%</td>
</tr>
</tbody>
</table>

It is, and should be assumed that subsidies either reduce or ‘fade out’ over time. If this is articulated by policy makers it does not need to impact project feasibility. It is assumed that both the technology learning curve and project economies of scale will reduce the unit cost of production over time, thus reducing the reliance on subsidies. Interest free loans or project grants simply tackle the high discount rate conundrum at the start of a capital intense project in an embryonic industry.
4.3.3 Potential solutions to bridge the valley of death:

This section outlines some suggested steps that policymakers can consider in helping their air transport system grow with less carbon-intensive fuel, whilst in many cases also investing in green growth jobs and a new sustainable industry.

4.3.3.1 Research

There are many different types of feedstock and pathways that enable feedstock to be converted into biofuel, and important technological developments will unlock still more pathways.

The aviation industry is unlikely to rely on a single feedstock, or source of the fuel. Some feedstocks are better suited to some climates and locations than others. Therefore, it is expected that ultimately there will be a portfolio of biofuel sources developed and a variety of regional supply chains.

Research and Development of drop-in fuels particularly those focused on aviation fuels is desirable. Additionally, the automotive sector would benefit from drop-in fuels, which do not have the same blend percentage limitations as current biodiesel and bioethanol.

Policy enablers include providing funding programs for existing or new research projects by universities, research institutions and industry, broadening or re-focusing research of advanced fuels to include aviation-specific projects.

4.3.3.2 De-risk public and private investment in sustainable aviation fuels

To be economically viable, sustainable aviation fuel must be priced at a level competitive with the fossil alternative plus the price of carbon. Presently, most alternative fuels for aviation are not cost competitive with current jet fuel. However, despite recent weakness in the oil price, over the longer term, traditional jet fuel is forecast to become more expensive. By contrast, sustainable aviation fuel will become less expensive as the industry develops. Policies incentivizing alternative fuel development and use can hasten this trajectory and achieve greater emissions reductions in a shorter timeframe.

A better appreciation of the scope for reduction in the price of sustainable aviation fuel is gained by examining the cost drivers. As technology to harvest and process feedstocks progresses, and as agronomy and plant breeding, produce cultivars with better, more robust yields, and as sustainable biomass become available in commercial quantities the price will drop. In fact, since aviation biofuel testing started, prices for these feedstock inputs have already dropped significantly16.

Support for research and development will enable continued improvements for feedstock pathways.

Production is the second major component of the total cost of the fuel. The oil industry has already established refining infrastructure and thus currently has a limited need for additional capital investment. However, in the case of sustainable aviation fuel, the production infrastructure has yet to be developed and some of what needs developing could be synergistic with existing petroleum infrastructure, but not all.

There are also significant subsidies in place for biodiesel and bioethanol production in Europe and the US, which incentivizes directing biofuel feedstock into the automotive rather than the aviation sector creating a financial disincentive for the establishment of alternative aviation fuel production.

These incremental upfront capital investment costs are a potential barrier to commercialization. In this context, governments can play a role in reducing this risk through measures such as loan guarantees, tax incentives, grants and co-financing for pilot and demonstration projects. They can also provide a level playing field with biodiesel by providing similar fiscal and price incentives in order to catalyze establishment of the sector.

4.3.3.3 Provide incentives for airlines to use alternative fuels from an early stage

Few industries are as competitive as aviation. This produces excellent outcomes for State economies and consumers. Aviation profits have historically trended below the weighted average cost of capital meaning consumer’s and national economies receive the benefits of aviation below the true cost. The impact of this situation is the aviation sector is often cautious making a business decision involving unquantified risk or potentially subjecting an airline to a competitive disadvantage. Hence, airlines need encouragement to use alternative fuels from an early stage.

The aviation industry has committed to ambitious goals for reducing emissions. Sustainable alternative fuels are an important part of the plan to reach these goals and the industry and its partners have made significant progress. From policymakers, the industry is looking for the right set of legal, fiscal and policy responses to ensure this new energy stream can be incorporated into business as usual as quickly as possible.

4.3.3.4 Robust international sustainability criteria

As mentioned in this report, sustainability standards are established to provide suppliers, investors and customers with clear guidelines as to what is considered to be a sustainable fuel.

Sustainability is not just a matter of the choice of feedstocks — it is also a matter of how they are cultivated, harvested, processed and transported. Some key sustainability criteria for aviation fuels could include the following elements:17

- will not displace, or compete with, food crops or cause deforestation
- minimize impact on biodiversity
- produce substantially lower life-cycle greenhouse gas emissions than conventional fossil fuels
- will be certified sustainable with respect to land, water and energy use
- deliver positive socioeconomic impact.

As a global transportation sector, aviation requires a harmonized standard to ensure that sustainability criteria are equally applied across the industry. A patchwork of standards inhibits the development of a commercially viable market. It is also vital that a unified accounting structure be established to verify the origin and sustainability credentials of these new fuels for aviation. A future ICAO global MBM will be an ideal driver to achieve this.

The development of an accepted set of globally harmonized standards will help ensure that investment is directed at fuels that meet acceptable sustainability criteria, thus minimizing this form of risk. Criteria need to be mutually recognized around the world. For aviation, global standards are needed wherever possible, due to operational routing of aircraft, common global equipment and worldwide fuel purchasing requirements.

4.3.3.5 Foster local opportunities

Sustainable aviation fuel doesn’t only bring environmental benefits for aviation, it can also foster the development of a new industry. Given the diversity of feedstocks that can produce sustainable alternative fuel, there are few places that could not support some development of a new, sustainable, energy industry. These can range from growing large quantities of jatropha, halophytes or camelina in the most appropriate environments, to establishment of algae farms on land or off-shore, to biofuel facilities in cities utilizing municipal waste.

By bringing the aviation industry, government, energy, agriculture and academic expertise in a country or region together, analyze the optimum opportunities that exist in each country for aviation biofuel production, including the most effective feedstock sources and infrastructure requirements. Regional development banks can play a proactive role in developing this process.

17. http://www.safug.org/
4.3.3.6 Policy equality

Only in 2009 was the first production pathway for aviation fuel approved by the technical standards body ASTM International. This put the sector some years behind ground transport. It has also created a policy imbalance. Many countries provide subsidies for the production of ethanol or biodiesel. This is one reason why the majority of renewable fuel produced hitherto has been for the ground transport sector, and it continues to be more profitable for a feedstock producer to produce for this sector rather than for aviation.

It is vital to provide a level policy playing field to enable aviation demand to compete equally. Additionally, 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.
4.3.4 Chapter references

[1] U.S Environmental Protection Agency, Renewable Fuels Compliance Help
http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-aq.htm#1


5. National and International Biojet programs

5.1 Chapter summary

This chapter provides a description of some recent biofuel developments from industry stakeholders. While in this chapter the Indonesian Alternative Fuels and Renewable Energy Initiative is presented in some detail a number of initiatives detailed in earlier editions of the Report on Alternative Fuels continue to make progress.

- In the US, the Defence Logistics Agency are involved in numerous initiatives supporting the certification and commercialization of alternative aviation fuels, including the Green Initiative for Fuels Transition Pacific and the provision of technical and contracting support in an Advanced Drop-In Biofuel Production Project being established under the authority of Title III of the 1950 Defense Production Act (DPA).
- In Spain SENASA and 12 partners from 9 different countries are continuing to advance the ITAKA (Initiative Towards Sustainable Kerosene for Aviation), project integrating a full production and use value chain.
- While in Germany, 2014 marked the second year for aireg and progress was achieved towards their strategy for a prompt market introduction of alternative aviation fuels.

Some new initiatives in 2014 of note were:

- 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; and
- the BIOjet Abu Dhabi initiative pursuing the setting of a supply chain in the United Arab Emirates.

IATA gratefully acknowledges the contribution from Yusfandri Gona and Cesar Velarde for their contribution to this chapter.

5.2 The Indonesian Alternative Fuels and Renewable Energy Initiatives

5.2.1 Background and overview

As an archipelagic country, air transportation has a major role in connecting the islands and vast areas of Indonesia.

As the current and future growth of the aviation industry affects global warming, the Indonesian Directorate General of Civil Aviation (DGCA) has expressed its commitment for the reduction of GHG emissions in accordance with ICAO and IATA global policy by developing "The Indonesia Aviation Green Initiatives on Mitigation of Climate Change and Reduction of Green House Gas Emissions" which has a focus are: Green Flight, Green Corridors and Green/Eco Airports.

Among its main pillars DGCA in close cooperation with National stakeholders, is developing the "The Alternative Fuels and Renewable Energy for Airports Initiatives".

These measures will be implemented gradually to maintain the benefits of air transport growth, employment absorption and contribution to the national economy, while implementing an environmentally compatible policy framework.

The Renewable Energy for Airports Initiative aim to achieve a total of 7.5 MW renewable energy capacity (3% of Total Capacity) by 2020 supplied by solar, wind and biomass based technology at Indonesian airports. This chapter refers only to the implementation of an aviation sustainable alternative fuels program in Indonesia.
5.2.2 Objectives and timeframe

The Indonesian sustainable alternative fuels program for aircraft operation is planned to be implemented in two stages:

- An initial pre-implementation phase (2014-2016): This phase includes (see Figure 7)
  - the development of an industrial pilot study,
  - research and development activities,
  - testing and certification,
  - feasibility studies for investment,
  - development and cultivation of sustainable raw materials,
  - manufacturing and production,
  - definition of quotas, price level and economic markets,
  - distribution and quality assurance, as well as Risk Management.

- A second implementation phase (2016-2020) considering the
  - implementation of a sustainable alternative fuel mix of 2% in 2016-2018, through voluntary agreements among the Indonesian authorities and airlines operating in their airports,
  - if feasible, an increase to a 3% mandatory mix for all carriers in 2018-2020.

---

**Figure 7 – Roadmap for Aviation Biofuels Initiative**
The DGCA-Indonesia as regulator will develop and implement a Monitoring Reporting and Verification (MRV) system to follow-up the achievement of the initiative’s objectives.

The estimated potential emissions reduction by implementing 2% sustainable alternative fuels will reach 0.323 - 0.379 MtCO₂/year in the period 2016-2017, and increase to 0.583 – 0.729 MtCO₂/year in the period 2018-2020. Thus the potential accumulation of carbon emission reduction up to 2020 will achieve 2,725 MtCO₂ or contribute equivalent of 17% of total emissions reductions in the air transport sector (see Figure 8).

The implementation of sustainable alternative fuels in air transport will therefore significantly contribute to the national emission reduction objectives, complementing the improvement of local air quality and noise abatement, fuel supply security and price controls, enhancement of the maintenance efficiency and aircraft utilization, while adhering to the existing strict jet fuel technical standards.

5.2.3 Development of a policy and regulatory frameworks

Existing legal framework in Indonesia, including aviation and the environmental regulations, is sufficient to initiate the alternative fuels and renewable energy programs; There are already several policy frameworks in place to develop them, such as the Presidential Decree on the National Action Plan on GHG emissions reduction or the Decree of Ministry of Transportation for sub-sector of air transportation.

But additional regulatory frameworks will need to be promoted, in order to establish the necessary legal framework to enable the implementation program of sustainable alternative fuels such as:

- Government Regulations for fuel quality assurance in the form of standards, specifications, guidelines for testing, certification and distribution;
- Government policies to provide incentives for investors and manufacturers to scale-up production of sustainable alternative fuels for aviation, including the operators as end users in order to encourage the interest of the private sector to contribute on this program.

- Sustainability assurance provisions: The Indonesian Government will put in place the necessary framework, based on Indonesian and internationally recognized sustainability standards, to warrant the sustainability of the feedstocks used and the complete value-chain involved on the alternative fuel production.

This initiative is in line with the Indonesian Government’s ambition to extract more local benefits and revenue from Indonesian resources. The country has on the last years focused on the export of raw commodities (such as crude palm oil and coconut) but has shifted its priority to refined products with higher added value in the production chain.

5.2.4 National stakeholders involvement

There have been recruited about 75 experts and professionals from various organizations (government, universities, oil producers, airliners, airport operators, national and international associations) to join the “Aviation Biofuels and Renewable Energy Task Force (ABRETF)” and the Indonesian Government Climate Change Task Force under the Ministry of Transportation, and the Ministry of Energy and Mineral Resources. The kick-off meeting of ABRETF was conducted in March 2014. This Task Force is formed by four Sub Working Groups:

- Policy, Regulation and Capacity Building.
- Research and Development.
- Testing and Certification.
- Commercial evaluation, Risk Assessment and Sustainability.

The success of the program will depend on the commitment of all involved industry stakeholders. Among them, are key national stakeholders such as the airlines Garuda and Indonesia Air Asia as well as the fuel company Pertamina.
5.2.5 Feedstock & Sustainability

There is a range of feedstocks that can be used in Indonesia to produce sustainable biofuels for aviation. Indonesia is the world’s largest producer of Crude Palm Oil, and the initiative is currently assessing the potential of its use, among others, under solid sustainability requirements.

The Indonesian Ministry of Agriculture in partnership with the United Nations Development Programme (UNDP) has launched in 2014 the Sustainable Palm Oil Initiative (SPOI), a national platform aiming to support low-income palm oil farmers to increase productivity and improve environmental management and promote the Indonesian Sustainable Palm Oil (ISPO) requirements which aims to enhance the global competitiveness of Indonesian palm oil under stricter environmental legislation.

There is the potential to generate positive social impacts such as job creation, income generation and development of rural and local communities.

As mentioned above, the Indonesian Government will put in place the necessary framework to warrantee the sustainability of the feedstocks used for aviation biofuels production, based on recognized sustainability standards and certification schemes.

5.2.6 ICAO Cooperation

In order to assist these Task Forces in performing their function, the DGCA Indonesia has signed an agreement with the ICAO Technical Cooperation Bureau (TCB).

Such cooperation with ICAO TCB will contribute to supporting Indonesia to develop a capacity building program and establish a professional permanent environmental restructure within DGCA Indonesia.

These initiatives are also framed in the cooperation between Indonesia and ICAO and are aligned with its increasing participation in the work of the Committee of Aviation and Environmental Protection (CAEP). Among others, Indonesia will aim to provide a significant contribution to the work of the CAEP Alternative Fuels task Force.
There is a potential of generating positive social impacts such as job creation, income generation and development of rural and local communities.

As mentioned above, the Indonesian Government will put in place the necessary framework to warrantee the sustainability of the feedstocks used for aviation biofuels production, based on recognized sustainability standards and certification schemes.

5.2.6 ICAO Cooperation

In order to assist these Task Forces in performing their function, the DGCA Indonesia has signed an agreement with the ICAO Technical Cooperation Bureau. Such cooperation with ICAO TCB will as well support Indonesia to develop a capacity Building program and establish a professional permanent environmental restructure within DGCA Indonesia. These initiatives are also framed in the cooperation between Indonesia and ICAO and are aligned with its increasing participation in the work of the Commetee of Aviation and Environmental Protection (CAEP). Among others, Indonesia will aim to provide a significant contribution to the work of the CAEP Alternative Fuels task Force.

Figure 1: Roadmap for Aviation Biofuels Initiative

Figure 2: CO₂ Emissions Reductions from Indonesian Green Aviation Initiatives

5.3 The Air Transport Institute for Environmental Sustainability (AirTIES) Research Center

The interest in and demand for sustainable technologies has increased dramatically in recent years, leading to an expectation today that college graduates will be knowledgeable and prepared to support initiatives in this area. Answering to these challenges in the broad space of aviation operations, the Air Transport Institute for Environmental Sustainability (AirTIES) Research Center at Purdue University developed a new graduate Area of Concentration (AOC) entitled “Sustainable Aviation and Transportation Operations”. The four courses in this AOC are part of the existing Aviation Technology Master’s plan of study and provide in depth coverage of topics of sustainability in aviation, aviation fuels, advanced technical support, and aviation finance.

This year, Brian Kozak, an Aviation Technology student, completed a PhD focused on aviation bio-fuels. A second PhD student is now following the path Brian blazed, and is concentrating his efforts in exhaust emissions of alternative aviation fuels. This program is unique in that the plan of study leverages the benefits of both academic rigor and practical applications, such that graduate students develop an array of knowledge, skills, and abilities in the arena of sustainable aviation fuels, exhaust emissions, and research and testing procedures.

Given the many sustainability issues confronting aviation, the mission of this Center is two-fold: education and research. AirTIES supports the latter with in-house faculty expertise for fuels, emissions, and engine testing, as well as through collaborative relationships with other disciplines across the University involved in the development of new aviation fuels, and by teaming with industrial partners committed to issues of sustainability.

Education and knowledge distribution plays an important role in the development of new industries. As momentum for aviation biofuel courses grows, this will make a positive contribution to the commercialization of biofuel deployment.

IATA gratefully acknowledges the contribution of Denver Loop in section 5.3.
6. Notable Developments

6.1 Chapter summary

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

- In Abu Dhabi, Etihad is leading the way in the Middle East and this year announced a collaboration with Boeing, Masdar Institute, Takreer and TOTAL in launching ‘BIOjet Abu Dhabi, Flightpath to Sustainability’.
- From Australia, Qantas and Shell Australia completed a landmark piece of research to understand the economic viability of producing aviation biofuel in Australian on a commercial scale using existing supply chain and refining infrastructure and certified aviation biofuel pathways.
- Leading biojet fuel logistics company SkyNRG made advances in many areas including a growing corporate program, establishing SkyNRG Nordic and launching project Solaris, a feedstock project in South Africa.
- Cathay Pacific invested in Fulcrum Bioenergy and announced the largest alternative jet fuel offtake agreement to date of 375 million gallons over 10 years.

6.2 Driving Alternative Sustainable Aviation Fuels in Abu Dhabi

Etihad Airways recognises the role alternative fuels will play in the future sustainability of the airline industry, a view that is gaining wider representation throughout the world, but also with governmental policymakers. Accordingly, Etihad Airways is at the forefront of a global movement towards alternative sustainable fuels in the Middle East. IATA gratefully acknowledges the contribution of Linden Coppell of Etihad Airways to Section 6.2.

6.2.1 BIOjet Abu Dhabi: Flightpath to Sustainability

Whilst Etihad Airways efforts in this area started back in 2009, it was in the beginning of 2014 that a major initiative was announced to engage a broad range of stakeholders in government and civil society to build the common understandings and partnerships needed to develop the full alternative aviation fuel supply chain in Abu Dhabi.

On January 19th 2014 Etihad Airways announced its collaboration with Boeing, Masdar Institute, Takreer and TOTAL in launching ‘BIOjet Abu Dhabi, Flightpath to Sustainability’.
There are three integrated production systems of ISEAS that leverage each other’s co-products for sustainable operations:

- Aquaculture ponds isolated from coastal waters in which shrimp and/or fish are grown, partly fed by meal from halophytes.
- Fields of saltwater tolerant ‘halophytic’ plants irrigated by nutrient-rich discharge water from aquaculture ponds, producing oil and biomass fuel feedstocks, animal feed and high-value chemicals – transforming an aquaculture pollution problem into a fuel, chemical and fertilizer resource.
- Created mangroves that eliminate nearly all remaining nutrients before water is discharged into coastal waters, and which can provide biomass for fuel feedstocks from coppiced trees. Mangrove forest increase habitat opportunities for birds and other species, create ecotourism opportunities and lock carbon into roots and soils in the long term.

There has been significant interest in the project, especially as aquaculture is being encouraged in the UAE to support food security and the Environment Agency Abu Dhabi has produced an aquaculture strategy entitled *Supporting Sustainable Aquaculture Development in Abu Dhabi Emirate*. The Environment Agency sees the ISEAS as a potentially significant means for the sustainable treatment of aquaculture wastewater.

The SBRC partners aim to take ISEAS to commercial scale through pilot and demonstration efforts. For this, the SBRC has developed a plan for ISEAS scale-up to take place in three stages:

BIOjet Abu Dhabi was announced one day after Etihad Airways conducted a demonstration flight with a Boeing 777 powered in part by the first UAE-produced aviation biofuel from an innovative plant biomass-processing technology. The biofuel was partially converted from biomass by Total and its partner Amyris. Takreer, the wholly owned oil-refining subsidiary of Abu Dhabi National Oil Company (ADNOC), did the final distillation, adding the UAE to a handful of countries that have produced and flown on their own aviation biofuel.

Led by the airline, BIOjet Abu Dhabi is engaging a broad range of stakeholders to develop a comprehensive framework for a UAE biofuel supply chain with the first key milestone for BIOjet Abu Dhabi being the development of a roadmap for Abu Dhabi.

The roadmap is currently under preparation with the first round of stakeholder dialogue completed. The dialogue was extensive and included discussions with many government and civil society entities in the UAE.

The draft roadmap was distributed to stakeholders in October 2014 and further direct dialogue will follow. The roadmap will be published during the World Future Energy Summit in Abu Dhabi in January 2015, as an action orientated report, mapping the requirements to ensure a commercially viable and fully sustainable aviation fuel supply for Abu Dhabi and the UAE.

### 6.2.2 The Sustainable Bioenergy Research Consortium (SBRC)

Linked closely with this, as a fundamental component of a viable supply chain is the work of the Sustainable Bioenergy Research Consortium (SBRC).

Led by the Masdar Institute with funding partners including Etihad Airways, The Boeing Company, UOP Honeywell and Safran the SBRC is pioneering the Integrated Seawater Energy and Agriculture System (ISEAS). ISEAS is an effort to develop a novel form of agriculture, producing food and fuel on traditionally non-arable desert land irrigated with seawater. With seawater comprising 97 per cent of the world’s water supply, it has potentially high sustainability credentials in a water constrained region.
There are three integrated production systems of ISEAS that leverage each other’s co-products for sustainable operations:

- Aquaculture ponds isolated from coastal waters in which shrimp and/or fish are grown, partly fed by meal from halophytes.
- Fields of saltwater tolerant ‘halophytic’ plants irrigated by nutrient-rich discharge water from aquaculture ponds, producing oil and biomass fuel feedstocks, animal feed and high-value chemicals – transforming an aquaculture pollution problem into a fuel, chemical and fertilizer resource.
- Created mangroves that eliminate nearly all remaining nutrients before water is discharged into coastal waters, and which can provide biomass for fuel feedstocks from coppiced trees. Mangrove forest increase habitat opportunities for birds and other species, create ecotourism opportunities and lock carbon into roots and soils in the long term.

There has been significant interest in the project, especially as aquaculture is being encouraged in the UAE to support food security and the Environment Agency Abu Dhabi has produced an aquaculture strategy entitled *Supporting Sustainable Aquaculture Development in Abu Dhabi Emirate*. The Environment Agency sees the ISEAS as a potentially significant means for the sustainable treatment of aquaculture wastewater.

The SBRC partners aim to take ISEAS to commercial scale through pilot and demonstration efforts. For this, the SBRC has developed a plan for ISEAS scale-up to take place in three stages:

- A two-hectare ISEAS pilot is under development at Masdar City.
- A 200-hectare demonstration site has been selected along the Abu Dhabi coast.
- With operational and economic questions answered, commercial operations can be launched.

The pilot project will be completed and operational by early 2015.

Etihad Airways is wholly committed to this program, confirmed through its US$2 million contribution to the SBRC and its leadership role in the BIOjet Abu Dhabi initiative.

### 6.3 Australian feedstock and production capacity to produce sustainable aviation fuel

#### 6.3.1 Background

In 2013 Qantas and Shell Australia completed a landmark piece of research to understand the economic viability of producing aviation biofuel in Australian on a commercial scale using existing supply chain and refining infrastructure and certified aviation biofuel pathways.

The study, conducted with the support of the Federal Government, found that an aviation biofuel industry in Australia is technically viable but significant obstacles to commercial viability remain. IATA gratefully acknowledges the contribution of Flyn van Ewijk of Qantas for the contribution to Section 6.3.

Identifying natural oils (HEFA) as a proven source material, the study modelled a plant capable of producing 1.1 billion litres of renewable fuels, including jet fuel and diesel, per year using existing supply chain infrastructure. The study partners assessed the commercial viability of a 3,000 tonnes-per-day reference facility, which would produce approximately 20,000 barrels of renewable hydrocarbons (diesel, aviation biofuel, naphtha and refinery gas) per day. Depending on the process configuration, the aviation biofuel fraction was between 5% and 35% of Qantas’ current domestic fuel demand when certified in a 50:50 blend.

Qantas, with support from Solena, also assessed the commercial feasibility of a Fischer Tropsch (FT) using municipal solid waste. Although a waste-to-fuel FT plant in Australia has potential, key assumptions remain unproven. This study examined a specific project for Australian conditions based on the British Airways-Solena GreenSky London FT venture, which uses municipal solid waste (MSW) as feedstock. Capital expenditure for this project is approximately US$500 million (2012 figures), assuming a brownfield site. The renewable plant would produce approximately 40% aviation biofuel, 40% diesel and 20% naphtha. This is equivalent to 1,000 barrels of aviation biofuel per day, or 5-7.5% of Qantas’ current domestic fuel demand when certified in a 50:50 blend.
6.3.2 Key stakeholders

To investigate the conditions under which an Australian-based aviation biofuel industry could be commercially feasible, Qantas formed a joint study team with The Shell Company of Australia Limited (Shell) and study partners, Sinclair Knight Merz (SKM), AltAir, the Australian Research Council (ARC) Centre of Excellence in Plant Cell Walls at the University of Adelaide and SkyNRG. The project scope was specifically designed to review the commercial and long-term viability of aviation biofuel, using certified refining technology and infrastructure in Australia. Therefore, the project partners focused exclusively on the production of aviation biofuel from hydroprocessed natural oils and animal fats (the HEFA pathway). To augment understanding of the production of aviation biofuel from the certified Fischer Tropsch (FT) pathway, Qantas – independent of the main study partners – commissioned Solena to provide industry insights.

The project was supported by a $575,000 grant from the Australian Government, while Qantas and Shell contributed $375,000 in-kind.

6.3.3 Key findings – commercialisation challenges

Consistent with the previous Australian research this study found that the establishment of an aviation biofuel industry in Australia is technically feasible. However, to effectively unlock the opportunity that aviation biofuel represents there are significant challenges to achieve commercial feasibility with regard to the HEFA and FT pathways.

Natural oils to fuel (HEFA pathway)

From a technical perspective, the conversion of natural oils and animal fats into renewable fuels using hydro-processing technology is technically feasible and is already occurring at commercial scale in several bio-refineries around the world. However, these bio-refineries target renewable diesel production for subsidised markets, only producing aviation biofuel on an opportunistic basis, if at all.

Capital expenditure for the reference facility (20,000 bpd) is approximately AUD$1 billion (2012), which is consistent with industry cost values when considering that the construction of additional, as opposed to the conversion of existing, hydroprocessing equipment is required in Australia.

The key findings which impact the commercial viability of an aviation biofuel manufacturing industry and supply chain in Australia include:

1. Feedstock economics

The main commercial barrier to developing a hydro-processed natural oil and animal fat-based industry in Australia is that the price of feedstock is generally higher than the price of unsubsidised end products, such as diesel and jet, as illustrated in Figure 9 (using dated Brent Crude as a proxy for jet fuel). Under these conditions, the economics of an aviation biofuel value chain is not viable.

Figure 9 – Relationship between crude oil and oil feedstock prices
2. Feedstock volume

Although in theory there is enough natural oil volume in the total Australian market to supply the reference bio-refinery, in practice, there is very limited rateable domestic feedstock currently available, at the right price. The available volume of natural oils from existing feedstock and land availability is therefore insufficient to support a significant aviation biofuel industry today. The study also found that imported commodity vegetable oils would be difficult to rely upon over the medium to long term.

![Figure 10 – Domestic HEFA feedstock production, consumption and export (millions of tonnes per annum)](image-url)

* 0.15 excluding brown grease

Figure 1: Relationship between crude oil and oil feedstock prices
3. Feedstock sustainability

The preference of the study partners was to maximise the use of non-food competing feedstock, and to avoid feedstock sourced via unsustainable land use or that breach human rights, consistent with the sustainability practices of the key study partners. In general, sustainable feedstock, such as those highlighted in Figure 11 is in very short supply, attracts a premium to the market price or requires further research and development.

![Sustainable feedstock examples](image)

4. Pricing competitiveness

The study identified a clear correlation between natural oil prices and crude oil price, as illustrated in Figure 8. Traditionally, when the price of crude oil goes up, the perception has been that bio-fuels become more competitive. The study observed that natural oils prices are correlated to crude oil prices, so both products tend to move in the same direction. Therefore, at least for the case of bio-fuels derived from natural oils, the increasing price of crude oil tends to lead to increases in the price of aviation biofuel.

5. Manufacturing

While the final bio-fuel products can be integrated into existing supply and distribution infrastructure, significant modifications are required to current refineries to process natural oils and animal fats to aviation fuel. A brownfield (existing) refining site is the lowest cost option but still represents a significant capital outlay. In addition, most Australian refineries have insufficient hydrogen to process natural bio-oil or tallow feedstock. Therefore additional hydrogen must be manufactured onsite, which adds significant capital and operating cost.
6. Diesel versus aviation biofuel

Australian natural oils and tallow feedstock naturally produce a diesel product. Converting diesel to aviation biofuel reduces the economic return of the bio-refinery due to increased production of lower value products (i.e., naphtha and gas), as illustrated in Figure 12.

Consequently, to establish a commercially viable HEFA manufacturing industry and supply chain in Australia, the following conditions would need to exist:

1. Access to substantial and rateable volumes of existing natural oil and/or tallow feedstock at significantly less than current market prices;
2. The ability to ramp up emerging and non-food domestic feedstock production programs to provide rateable feedstock volumes at attractive prices, which reflect a weaker price correlation between feedstock and crude-oil; and
3. A balanced policy environment that incentivises the production of all renewable transport fuels equally.

Waste to fuel (FT pathway)

Conversion of gas and coal-based feedstock into hydrocarbon products (e.g., fuels, waxes and chemicals) has been commercialised using the Fischer Tropsch (FT) process. Production of renewable hydrocarbons from biomass (including municipal waste) feedstock via FT is theoretically possible; however, this has not been demonstrated at commercial scale. Application of the equivalent FT process components to the Australian context has determined that a project may have potential in Australia. High level waste market data suggests there is enough relevant waste in Sydney or Melbourne for a commercial plant requiring 500,000 tonnes per annum. In addition landfill levies in both Sydney and Melbourne are relatively high, providing a cheaper alternative to waste disposal for waste aggregators if an FT plant were to exist. However, the following conditions would need to be satisfied for an FT plant in Australia to achieve commercial feasibility:

1. Waste supply: Ability to negotiate with Australian waste companies to receive payment for long-term (greater than 10 years) waste supply agreements
2. Appropriate site: Ability to utilise a brownfield site with appropriate utilities in relative proximity to high waste volume sources in Sydney or Melbourne
6.3.4 Policy environment

The study also identified the importance of a supportive policy environment in facilitating the development of an advanced biofuels (aviation biofuel and renewable diesel) industry in Australia. It is recognised that constructing such an environment needs to be carefully considered and be complementary to other policy imperatives at the federal and state government levels.

To address the need to ramp up emerging feedstocks to commercial scale at competitive prices to fill the current gap in domestic sustainable supply, assistance might take the form of a targeted agricultural program in rural and regional areas. Such programs have the potential to encourage the development of promising feedstock alternatives, improve the productivity of marginal land without displacing existing land use and, ultimately, weaken the link between natural oil and crude oil prices. On a broader scale, such incentive based programs have the potential to facilitate the development of a new industry and related jobs in rural and regional areas.

In the interests of accelerating aviation biofuel development, consideration could be given to exploring policy means to ensure a level playing field in terms of government incentives for the production of biofuels. This will ensure producers aren’t provided with further incentive to target biodiesel or renewable diesel over aviation biofuel when making investment decisions.

6.3.5 Opportunities for Australia

The short term opportunities for aviation biofuel are to focus on improvements in the feedstock economics of the HEFA pathway and the technology readiness of the waste-to-fuel FT pathway. In addition, in the medium term, there is a significant opportunity to explore the feasibility of next generation pathways that have cheap and plentiful feedstock and that are likely to be certified by for commercial use in the near future. As identified by this report and previous reports, emerging pathways have the potential to involve feedstocks that are cheaper, more plentiful and more sustainable than natural oils feedstocks, that

The full report is available at www.qantas.com.au/environment
have lower capital expenditure than FT, and in which Australia has a significant advantage compared to the rest of the world.

In a similar manner to this study, future studies might involve key players in the supply chain to assess the practical and commercial conditions under which emerging pathways can lead to the establishment of viable advanced biofuel value chains.

6.4 Overview activities from SkyNRG

In 2014 SkyNRG expanded its activities in the international playing field and further developed its long term strategy to increase the sustainable jet fuel production capacity. This resulted in exciting new partnerships, the roll out of the Corporate Program, our first feedstock projects, and the establishment of new BioPort projects.

6.4.1 BioPort projects

A BioPort creates demand for sustainable jet fuel in the short term and enables investments in the development of a regional sustainable jet fuel supply chain for the long run. SkyNRG’s first BioPorts were set up in 2013; Brisbane BioPort with Virgin Australia and Brisbane Airport Corporation and BioPort Holland with KLM, Schiphol Airport, SkyNRG, Neste Oil, Port of Rotterdam and the Dutch Ministries of Infrastructure and Environment as well as Economic Affairs.

In 2014, Hayo de Feijter started working at SkyNRG with the single mission to expand the company’s feedstock business line. On August 6th, SkyNRG announced its first major feedstock project in South Africa, based on the Solaris technology. Solaris is a nicotine-free energy tobacco crop that’s developed by the Italian company Sunchem. SkyNRG and Sunchem SA have teamed up to roll out Solaris in Southern Africa at large scale to help power local sustainable jet fuel production. Both South African Airways (SAA) and Boeing will provide active support in securing further project financing and off take. However, in the first stage, the feedstock will be used within the BioPort Holland project, as there’s currently no production capacity in place, in South Africa.

Solaris can be used as a bio jet fuel feedstock that can help to significantly reduce cost price levels towards fossil parity and has the potential to reduce 80% of CO2 emissions compared to fossil kerosene. Next to the production of vegetable oil, the plant can be used for generating valuable animal proteins and biomass for rural electrification purposes. Solaris aims to demonstrate its sustainability by meeting the criteria of the Roundtable of Sustainable Biomaterials (RSB) standard which has been identified by the World Wide Fund for Nature and other international NGOs as the strongest sustainability guarantee on the market.
SkyNRG, Sunchem SA, Boeing, SAA and the RSB are already working together with Southern African stakeholders to position farmers with small plots of land to tap markets for biofuel feedstocks that provide socio-economic value to communities without harming food supplies, fresh water or land use. Soon we will see the benefits of certification, as smallholders improve their livelihoods through sustainable feedstock production. SkyNRG, Boeing and SAA anticipate growing Solaris on large-scale as well as for small-holder farms in the region. The consortium wants to raise further funding in the near future to reach critical scale as soon as possible.

6.4.3 SkyNRG Nordic

Early 2014, SkyNRG and Statoil Fuel & Retail Aviation AS announced to work together to commercialize sustainable jet fuel in the Nordic region by increasing the market “pull” on one side and by taking the first steps to create sustainable jet fuel supply chains, using local available feedstock. The parties are working together under the name SkyNRG Nordic.

The Nordic countries are very well positioned for the development of sustainable jet fuel, with an abundance of natural resources, public concern for the environment, and political support. Although primarily used in industry and in the heating sector, Biomass (mostly forestry) is already available today as an integral part of the modern energy system. Though, to date no sustainable jet fuel has been produced and no supply chain integration has occurred in the Nordic region. SkyNRG and Statoil Aviation have identified and expanded this opportunity to be the first companies to develop sustainable jet fuel in the Nordic region.

The strategy of SkyNRG Nordic is twofold. The company focuses both on short term supply and the long term development of local sustainable jet fuel supply chains. For short term supply, SkyNRG Nordic sources HEFA fuel and a local supply chain is developed. To bridge the existing premium for sustainable jet fuel, SkyNRG Nordic is engaging Nordic airlines, airports and corporate flyers to participate in the Fly Green Fund. The fund, made available through participating corporates that have the ambition to reduce their environmental impact from travel, will be invested in the acquisition of the first volumes of sustainable jet fuel and local BioPort projects.

In June 2014, Karlstad BioPort was announced, where the first volumes of sustainable jet fuel were used in Sweden on two flights with bmi and Nextjet departing from Karlstad Airport. The project started due to the interest of Karlstad Airport to make their business more sustainable. First steps are made with the establishment of an operational tank facility supplying sustainable jet fuel to all commercial flights departing from one single airport. The project also entails a long term track, where SkyNRG Nordic, The
Paper Province, SP Processum, and Karlstad Airport, are performing a feasibility study on establishing production of sustainable jet fuel. The study focuses on using available feedstock from the local forestry industry. Karlstad is strategically positioned between Oslo, Stockholm, and Goteborg and in the heart of one of the busiest pulp and paper regions in Sweden and in the world, with over 230 companies active in the industry.

Next to the partnerships established for Karlstad BioPort, SkyNRG Nordic teamed up with key aviation partners and the Nordic Initiative for Sustainable Aviation (NISA) to get sustainable jet fuel on the political agenda. Important highlights demonstrating this, are:

- Supplying Finnair with sustainable jet fuel for its biofuel flight to the New York UN Climate Summit in September 2014.
- Supplying SAS, in cooperation with Swedavia, with sustainable jet fuel for the Svebio Conference in Sweden early November 2014.
- Supplying Norwegian and SAS, in cooperation with Avinor and the NGO ZERO, with sustainable jet fuel for flights to Oslo in advance of the ZERO Conference.
- The established cooperation with the Haga Initiative and ZERO, which are leading NGOs in respectively Sweden and Norway that both work towards the reduction of carbon emissions from the business sector.

IATA gratefully acknowledges the contribution of Merel Laroy from SkyNRG for the contribution to Section 6.4.

Launch Karlstad BioPort, June 2014, Bio Jet Fuel Tank
6.5 Cathay Pacific Investment in Fulcrum Bioenergy

In August 2014, Cathay Pacific made a strategic equity investment in US based, Fulcrum Bioenergy. In addition to the investment, Cathay negotiated a 10 year, low carbon FT-SPK fuel offtake agreement, totalling 375 million gallons. Fulcrum and Cathay will work together to build multiple plants throughout North America, at locations strategic to Cathay destinations and will have supply at various US airports before 2020.

Fulcrum take mixed Municipal Solid Waste and via a process of feedstock pre-sorting, gasification with steam reforming, convert the waste into FT liquids. Further upgrading of these liquids results in FT-SPK fuel, that meets current D7566 specifications. The net CO₂ reduction when compared with fossil based fuel is approximately 80% however, as the methane produced by decomposing MSW is also avoided, additional environmental benefits can be realised. The Gasification part of the Fulcrum process is licensed from Thermochem Recovery International (TRI), a company with significant experience in the area of waste product gasification and value creation.

Fulcrum has physically produced jet fuel from MSW, at their demonstration scale facility. This was a key differentiator for Cathay when undergoing the due diligence part of the investment analysis. In addition, Fulcrum has 20 year, zero cost feedstock agreements in place with Waste Management and Waste Connections. These agreements cover the whole of North America, therefore ensuring that they have all the feedstock needed to produce the forecasted volumes of fuel, for the foreseeable future. Subsequent to Cathay investing, both the US Department of Agriculture and the Department of Defence issued loan guarantees and grants respectively, further underlining the confidence in the technology selection and business model.

Cathay is the first Airline to actually make a significant investment in an alternative jet fuel company and see their move as a game changer for the industry. Such a move paves the way for further strategic equity involvement by airlines in the field of sustainable fuels and to build on the momentum already generated by airlines that have collaborated or signed offtake agreements with, various fuel suppliers around the world. Several airlines have committed to biofuels and put great effort into building the initiative, by developing working groups and consortia. This is particularly evident in Europe and the US.
Cathay has put an initial focus on waste and residues as feedstock due to its abundance and lower sensitivity when concerning land use. More and more conversion technologies are being developed to take waste products in their various forms and convert to valuable products such as jet fuel. Aside from MSW, Cathay is looking into agricultural waste, waste gas streams and used oils. Crop based feedstock is also under initial review, in line with the company’s Sustainability Criteria and industry commitments through SAFUG.

IATA gratefully acknowledges the contribution of Jeff Ovens to Section 6.5. For additional information regarding Cathay Pacific’s alternative fuel program, contact Jeff Ovens at jeff_ovens@cathaypacific.com
Fulcrum Demo Plant
Glossary

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

Definitions

1st generation biofuel = biofuel produced from biomass that may compete with food production, degrade fresh water supply, cause deforestation and/or reduce biodiversity

2nd generation biofuel = biofuel made from sustainable, non-food biomass such as algae, jatropha, etc.

Agricultural residues = by-products from agriculture that are not or not well utilized

Alternative fuel = fuel from non-petroleum source

Anaerobic digestion = digestion in the absence of oxygen

Aromatics = molecule with a carbon ring of unsaturated bonds

ASTM D1655 = ASTM Standard Specification for Aviation Turbine Fuels

ASTM D7566 = Standard Specification for Aviation Turbine Fuels Containing Synthesized Hydrocarbons

Barrel = volume measure of 159 liters or 42 US gallons

Biochemical = processing material with organisms or enzymes

Biodiesel = alkyl esters derived from fatty acids

Biofuel = fuel produced out of biomass

Biojet fuel = jet fuel produced out of biomass

Biomass = renewable biological raw material such as plants, algae, organic waste etc.

Blend = mixing of different types of fuel

Butanol = alcohol with a 4-carbon atom based carbon chain

Carbon footprint = net amount of carbon dioxide emissions addressed to the applied product

Carbon neutral = with zero carbon footprint (CO2 emissions = CO2 absorption)

Catalyst = material that facilitates a chemical reaction

Cellulose = organic compound consisting of linked D-glucose units

Cloud point = temperature at which solids (wax) begin to form and separate from the fuel

Def Stan 91-91 = UK Defense Standard for Turbine Fuel, Aviation Kerosene Type

Density = mass per unit volume

Distillation = the separation of liquids by means of difference in boiling points

Drop-in fuel = alternative fuel that is indistinguishable from conventional fuel, with no changes of aircraft, engine or supply infrastructure required

Esterification = process to produce esters from fatty acids and alcohols, e.g. FAME and FAEE

Ethanol = drinkable alcohol with 2 carbon atoms

FAME/FAEE = Fatty Acid Methyl Esters/Fatty Acid Ethyl Esters – ester based biodiesels

Feedstock = raw material such as biomass, oils, fats, coal and gas

Forest residues = by-products from forestry industries

Fractionation = physical separation through progressive evaporation of volatile components

Freezing point = temperature at which a solid melts on warming

FT fuel = fuel produced with the Fischer Tropsch process

Fuel additive = additive to fuel to improve a certain property

Gasification = process transforming feedstock into CO and H2 under high temperature

Gallon = 3.785 Liters

Hydrocarbons = molecules made out of carbon and hydrogen, used as fuels

Hydrocracking = cutting down carbon chains under influence of hydrogen

Hydrogenated = raw material upgraded by hydroprocessing

Hydrotreatment = saturating and removing impurities in hydrocarbons using hydrogen

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

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEMP</td>
<td>Annual Emissions Monitoring Plan</td>
</tr>
<tr>
<td>AER</td>
<td>Annual Emissions Report</td>
</tr>
<tr>
<td>AFRL</td>
<td>Air Force Research Laboratory (USA)</td>
</tr>
<tr>
<td>AFTF</td>
<td>Alternative Fuels Task Force</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society of Testing and Materials (USA)</td>
</tr>
<tr>
<td>ATA</td>
<td>Air Transport Association (USA)</td>
</tr>
<tr>
<td>BTL</td>
<td>Biomass to Liquids (Fischer-Tropsch process)</td>
</tr>
<tr>
<td>BTU</td>
<td>British Thermal Unit</td>
</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
</tr>
<tr>
<td>CAAFI</td>
<td>Commercial Alternative Aviation Fuels Initiative (USA)</td>
</tr>
<tr>
<td>CAEP</td>
<td>Committee on Aviation Environmental Protection</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CTL</td>
<td>Coal to Liquids (Fischer-Tropsch process)</td>
</tr>
<tr>
<td>DLA</td>
<td>Defense Logistics Agency (USA)</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy (USA)</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency (USA)</td>
</tr>
<tr>
<td>ETS</td>
<td>Emissions Trading Scheme</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EUA</td>
<td>European Union Emission Allowance</td>
</tr>
<tr>
<td>EUAA</td>
<td>European Union Aviation Emission Allowance</td>
</tr>
<tr>
<td>FT</td>
<td>Fischer-Tropsch process</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration (USA)</td>
</tr>
<tr>
<td>FAE</td>
<td>Fatty Acid Ester</td>
</tr>
<tr>
<td>FAEE</td>
<td>Fatty Acid Ethyl Ester</td>
</tr>
<tr>
<td>FAME</td>
<td>Fatty Acid Methyl Ester</td>
</tr>
<tr>
<td>GE</td>
<td>Gasoline Equivalent</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GTL</td>
<td>Gas to Liquids (Fischer-Tropsch process)</td>
</tr>
<tr>
<td>HEFA</td>
<td>Hydroprocessed Esters and Fatty Acids</td>
</tr>
<tr>
<td>HRJ</td>
<td>Hydroprocessed Renewable Jet fuel</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>LCA</td>
<td>Lifecycle Analysis</td>
</tr>
<tr>
<td>LGE</td>
<td>Liters of Gasoline Equivalent</td>
</tr>
<tr>
<td>MJ</td>
<td>Megajoule</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>PARTNER</td>
<td>Partnership for Air Transportation Noise &amp; Emission Reduction</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td>RED</td>
<td>Renewable Energy Directive (EU)</td>
</tr>
<tr>
<td>RFS</td>
<td>Renewable Fuel Standard (USA)</td>
</tr>
<tr>
<td>RSB</td>
<td>Roundtable on Sustainable Biomaterials</td>
</tr>
<tr>
<td>SIP</td>
<td>Synthetic Iso-paraffin from Fermented Hydroprocessed Sugar</td>
</tr>
<tr>
<td>SPK</td>
<td>Synthetic Paraffinic Kerosene</td>
</tr>
<tr>
<td>SWAFAEA</td>
<td>Sustainable Way for Alternative Fuels and Energy in Aviation</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
</tbody>
</table>
Acknowledgements

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

Michel Adam - IATA
Robert Boyd – IATA
Linden Coppell – Etihad
Susanne Dekker – SkyNRG
Michael Gill – IATA
Yusfandri Gona – Indonesian Government
Andreas Hardeman – IATA
Rolf Hogan – Roundtable on Sustainable Biomaterials
Jane Hupe – International Civil Aviation Organization
Merel Laroy – SkyNRG
Denver Loop – Purdue University
Robert Malina – Massachusetts Institute of Technology
Philippe Novelli – International Civil Aviation Organization
Jeff Ovens – Cathay Pacific
Matthew N. Pearlson – Massachusetts Institute of Technology
Thomas Rötger – IATA
Mitch R. Withers – Massachusetts Institute of Technology
Flyn van Ewijk – Qantas
César Velarde – International Civil Aviation Organization