Powering the future of flight

The six easy steps to growing a viable aviation biofuels industry

AIR TRANSPORT ACTION GROUP

April 2011, web version

Acknowledgements

Many thanks to the following people and organisations who contributed their time and expertise to this publication:

Dr Alejandro Ríos, Aeropuertos y Servicios Auxiliares
Paul Nash and Florence Massat, Airbus
Nancy Young, Air Transport Association of America
Amy Bann, Darrin Morgan, Dr Michael Lakeman, Terrance Scott and Bill Glover, Boeing
Jonathon Counsell and Leigh Hudson, British Airways
Professor Minoo Patel, Professor Feargal Brennan and Ilze Lee, Cranfield University
Guilherme Freire, Embraer
Brian Pearce and Thomas Rötger, International Air Transport Association
And the Board of Directors of the Air Transport Action Group

Photographs and images provided by: Sapphire Energy (page 2, 4 and 14), Solena (page 11), Aeropuertos y Servicios Auxiliares (page 9), Boeing (page 16), KLM (page 15), Cranfield University (page 12), British Airways (page 11).

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Welcome to the biofuel age of flight

We have given this publication a subtitle "the six easy steps to growing a viable aviation biofuels industry" but of course this is not an 'easy' task. What we set out to do, however, is illustrate the potential for sustainable aviation biofuels to be produced in countries all over the world and provide concrete examples of how some countries and the aviation industry have already made substantial progress.

BY **PAUL STEELE**, EXECUTIVE DIRECTOR OF THE AIR TRANSPORT ACTION GROUP

We certainly have come a long way in a short time.

It wasn't many years ago that the idea of using biofuels for flight was dismissed out of hand on technical and safety grounds. Today, we have tested a range of biofuels in flight, we have made our way through a very tough technical standards process to ensure flight safety and we have been working hard to establish the correct sustainability criteria for the fuels we use.

We are now getting ready to take the next steps in the journey of alternative aviation fuels: ramping up to get enough of this low-carbon energy into our fuel supply.

Essential

Globally, aviation produces around 2% of man-made carbon dioxide (CO_2), according to the Intergovernmental Panel on Climate Change. But with the forecast growth in demand for air services, these emissions will grow if we do not take action. In response, the aviation industry has developed a set of ambitious targets aimed at limiting its climate impact, while enabling it to continue to provide a key vehicle for economic growth. The targets include: improving fleet fuel efficiency by 1.5% per year until 2020; capping net aviation emissions from 2020; and most ambitiously, to halve aviation CO_2 emissions by 2050, compared to 2005.

These targets were set after careful analysis and follow the industry's track record of measured progress, while also being far-reaching. But they cannot be achieved by technology or operational improvements within the aviation industry alone. Governments will have to play their part in ensuring that we can operate in the most efficient skies – with the needed improvements in air traffic control infrastructure and management.

One of the biggest opportunities to meet the 2050 target lies in low-carbon, sustainable aviation fuels, particularly biofuels. They are an essential component in meeting our targets and a vital step to reducing aviation's climate impact. Aviation has no alternative to liquid fuel for the foreseeable future, unlike ground transportation or power generation which have had a choice of energy sources for many years, even if they have not grasped this opportunity as quickly as they could have. Therefore, aviation must look to replace fossil fuels with lower carbon alternatives – and second generation biofuels are a perfect fit.

Viable

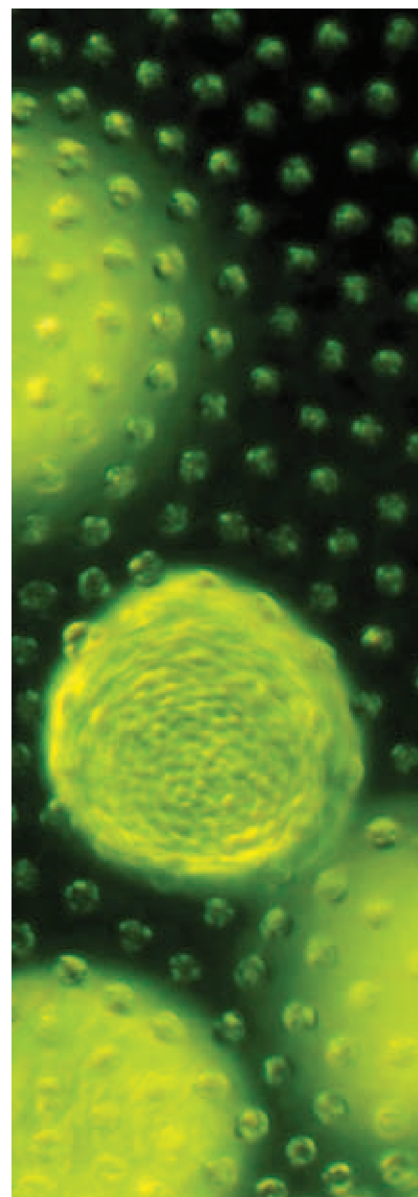
From a standing start just a few years ago, the aviation industry has embraced the concept of biofuels with enthusiasm and has already completed much of the technical work needed to start commercial flights. Rigorous testing, both on the ground and in the air, has shown that biofuels can deliver equal (and sometimes better) performance than the current fuel.

The biggest challenge now lies in ensuring a steady, reliable, cost-effective and sustainable supply of this new energy source. The fossil fuel industry has had a century to develop its fuel sources, supply chains and distribution networks. Not to mention its profit margins. The fledgling aviation biofuels industry will need to catch up and this will require capital from the investment community and start-up incentives from governments.

As a number of countries look to the green economy for growth in jobs and economic advantage, the fostering of a sustainable aviation biofuel industry will provide a double benefit – building green industry and making the vital tourist and business connections economically and environmentally viable.

Sustainable

There has rightly been a lot of unease about the impact that the first-generation of biofuels has had on both people and environments. Food price issues, land and water use and pollution have all been of great concern.
In beginning the process of looking at powering the future of flight through biofuels, the aviation industry has been extremely careful to try and avoid the mistakes made in the past.



→ COLLABORATION

Sustainable Way for Alternative Fuels and Energy for Aviation (SWAFEA)

This investigation of alternative aviation fuels feasibility and impacts from the European Commission's Directorate General for Transport and Energy is being conducted by an alliance of parties, representing all stakeholders from both biofuel and conventional fuel production up to aviation end-users.

"The steps may not be easy, but we can assure you the result will be worth it."

In many ways, we are fortunate that aviation is technically unable to use many of those first-generation fuels. Biodiesel freezes at the high altitudes at which we fly, for example, and ethanol doesn't carry the required energy density. So in aviation we have been looking at a wide range of non-food crops and sources of biofuel. We want to ensure that where crops are grown for aviation biofuels, that they are not taking the place of food crops. The industry has been working with organisations such as the Roundtable on Sustainable Biofuels to put in place the right sustainability criteria for aviation biofuels.

Cleaner

Without a doubt, aviation biofuels will have a big impact on the overall emissions of the aviation industry. Full lifecycle assessments of just some of the biofuel sources that have been explored so far show in excess of an 80% improvement on the fossil fuel currently used. While the industry is making some very significant steps in improving the efficiency of aircraft – since the first jets flew in the early 1960s, there has been a more than 70% improvement in fuel efficiency – technology can only take us so far. New fuels will help us achieve the targets we have set.

Practical

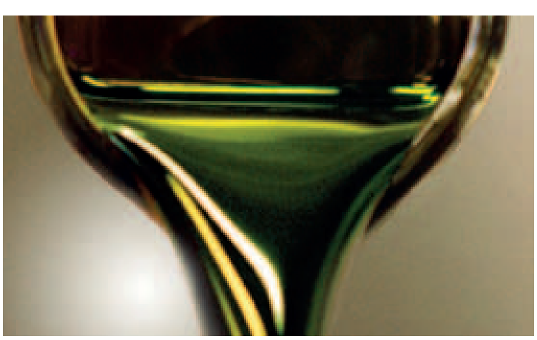
The second-generation biofuels that aviation is investigating are special – when refined, they are virtually identical to the Jet A-1 fuel we currently use. This means that we can simply drop them into the current fuel supply. No new engines, no new aircraft and no separate fuel delivery systems are needed at airports. It is the most practical solution. More biofuel can be added to the system as it comes on stream. We are striving to practically replace 6% of our fuel in 2020 with biofuel. We hope this figure can be higher.

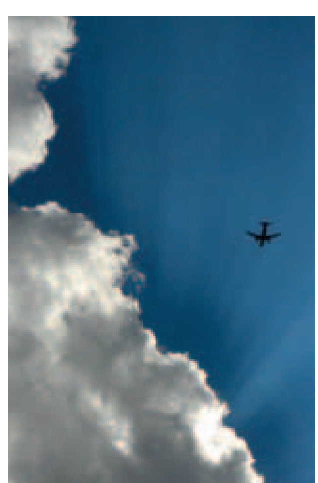
The supply of fuel to the commercial aviation industry is also on a relatively smaller scale and less complex than for other forms of transport. For example, there are over 160,000 retail gas stations in the United States alone. This compares to a relatively smaller number of airport fuel depots: 1,679 airports handle more than 95% of the world's passengers. For this reason, it is anticipated that it will be easier to fully implement the use of sustainable biofuels in aviation than in other transport systems.

It is also important to note that aviation is not looking at just one source of biofuel – we are investigating a range of alternatives as you will see from this publication. This will mean we can benefit from the most suitable feedstock in any given location and spread the sources for better security of supply.

It is clear that aviation is ready to become a major customer in the sustainable biofuel market. It is vital for our future and it is an important step in reducing carbon emissions. This publication, we hope, will provide some inspiration and ideas based on work already underway. It is not a comprehensive document – there are a great number of projects underway around the world to produce sustainable biofuels for aviation – but it does provide a few examples of different ways the challenge is being met. At the back, you will find some of the key steps we think need to be made in order to get the industry on the right flightpath to sustainable growth.

The steps may not be easy, but we can assure you the result will be worth it.





The economic case for biofuels

Biofuels for aviation have a number of benefits, the most important of which is the reduction in greenhouse gases emitted by aviation – an important conduit of world trade and economic development. But airlines will only be willing to move to sustainable fuels if there is a financial case. Currently, biofuels for aviation are rare and expensive. But as more and more supply comes on-stream, the costs will fall. The important milestone will be when the cost of biofuel reaches parity with the cost of using the current fossil fuel-based 'Jet A-1' for airlines.

BY **BRIAN PEARCE**, CHIEF ECONOMIST, INTERNATIONAL AIR TRANSPORT ASSOCIATION

Today it is not economical for airlines to use biofuels. Current estimates for the cost of producing biofuels suitable for air transport, suggest that airlines – and their passengers – would have to pay twice as much as they currently spend on jet kerosene. However, the economics of aviation biofuels and jet kerosene is likely to change.

There are three ways in which change will happen:

- First, government-imposed climate policies will add costs to users of fossil fuels.
- Second, the economics (and politics) of oil looks set to increase the price of jet kerosene.
- Third, the cost of producing and distributing aviation biofuel should fall.

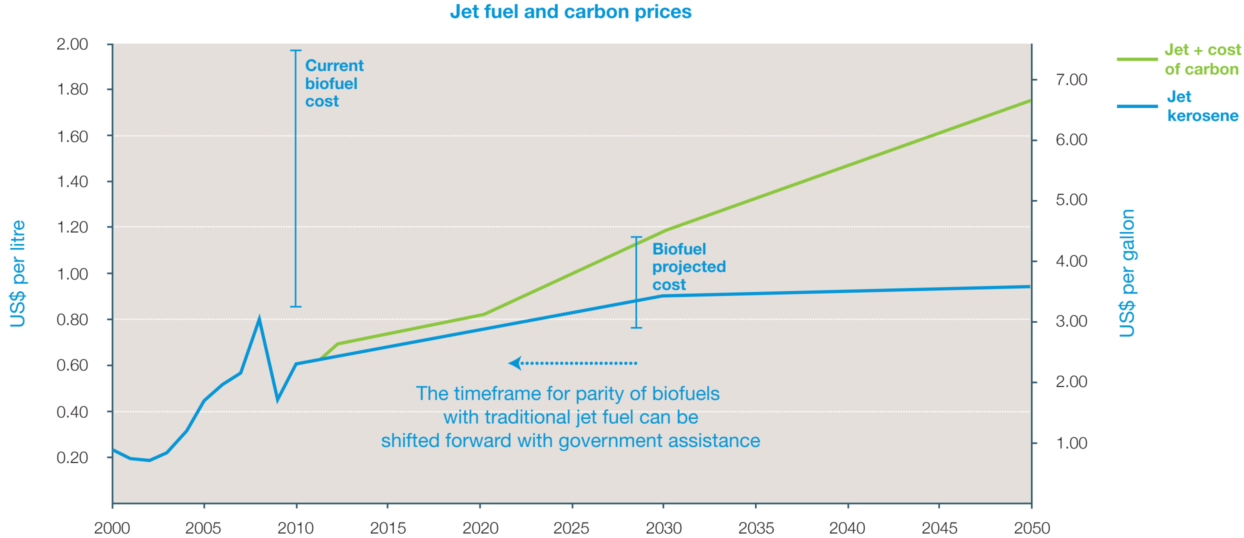
The speed and extent to which these three influences develop will determine how quickly biofuels become economic and how quickly they play a major role in reducing CO_2 emissions from air transport.

Cost of carbon

Climate change policy will likely change the economics of using jet kerosene. From 2012, as a result of the extension of the European Union emissions cap and trading scheme (ETS) to air transport, airlines flying to and from European airports will have to add the cost of carbon dioxide emission allowances to the cost of buying jet kerosene, unless overturned by pending legal challenges. The current price of €16 for an allowance to emit one tonne of CO_2 would add 2-3% to jet kerosene prices, closing the gap with biofuel costs only marginally. But allowance prices depend on the availability of cheap emission reduction options in certain sectors. Over time this low-hanging fruit will disappear and, by 2050, the cost of carbon is expected to double fossil fuel prices.

Climate policy costs for airlines may not have more than a marginal impact on the economics of aviation biofuels. From an aviation economics perspective, a more effective approach is to use positive economic measures at an early stage in the development of an aviation biofuel industry than waiting to rely on increasing costs of using fuels, which may come too late for aviation to be a user of biofuels.

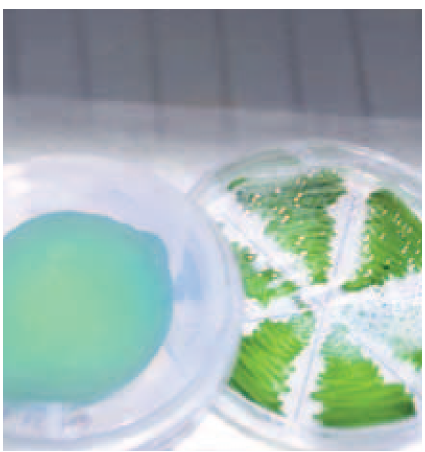
Jet fuel and carbon prices



Source: Jet kerosene price based on 25% markup over IEA's crude oil forecast in Energy Technology perspectives 2010. Carbon price taken from UK DECC 2010 central case forecast for traded carbon price. All are in constant (inflation adjusted) US dollars. IATA Economics. Schematic, indicative diagram.

→ COLLABORATION

Sustainable Aviation Fuel Users Group (SAFUG) *representing airlines that account for more than 20% of global commercial aviation fuel, has committed to drive development of commercial supply chains as well as support implementation of harmonised sustainability standards via the Roundtable on Sustainable Biofuels global multistakeholder processes.*



Black gold, or black platinum?

The economics of jet kerosene have already had a more significant impact than climate policies in making biofuels more economically viable. The rise in oil prices during 2008 was equivalent to a per tonne CO_2 allowance price of €100, compared to the current European ETS allowance price of €16. Early in 2011 the oil price once more surged through $100 a barrel showing its sensitivity both to demand from rapidly expanding emerging economies and to political turmoil in the Middle East. Oil and jet kerosene prices are currently four times higher than the average of the 1990s and early 2000s.

Peak oil proponents suggest the world is close to running out of this finite energy resource – in which case oil prices should continue to rise. But even if there are plentiful reserves of oil, it is still the case that new production oil is much more costly to extract. New fields being exploited are in deep or otherwise complex locations. Higher extraction costs will continue to exert upward pressures on oil prices, even without an impending shortage.

The view of many experts, including the International Energy Agency, is that these pressures will cause oil and jet kerosene prices to trend higher from now on. Adding the cost of buying CO_2 allowances it seems reasonable to forecast that by 2020 using jet kerosene will be at least as costly as the peak of the 2008 oil price spike. This will significantly close the cost gap between aviation biofuels and using jet kerosene. But even by 2020 rising fossil fuel and carbon costs may not be sufficient on their own to make aviation biofuels economic.

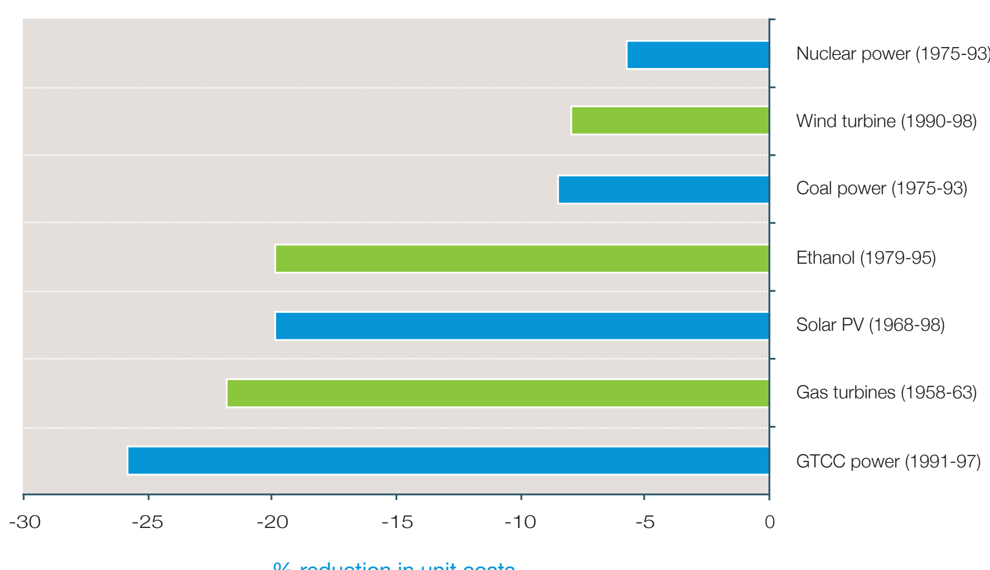
Production costs will fall

The key to improving the economics of using biofuels for air transport will be to significantly reduce unit production costs. This does look possible but it is a complex issue, not least because many of the biofuel technologies are in a very early stage of development.

Feedstock costs are a large proportion of costs in many of the newer biofuel technologies reliant on biological or chemical processes to convert biomass into fuel. Rising food prices today are indicative of the competition for arable land. Surface transport and power generation are also a source of increasing demand for energy crops. Put these competing demands together with a limited stock of land and the result is likely to be rising feedstock costs for aviation biofuels.

So reducing the unit production costs of aviation biofuels is likely to be dependent on big improvements in the productivity of feedstock, the extraction of oil or sugars from those crops, and the conversion into fuel. This means improved technology and innovation. Much has already been achieved. Venture capital and government funding is

Reduction in production costs with every doubling in capacity



Source: International Energy Agency

being sunk into a number of ventures. However, there are numerous different biofuel technologies being developed but few have yet been tested at commercial scale, and scale is one of the keys to getting unit costs down.

The experience of many energy technologies has been that as production capacity expands significantly economies are achieved through scale itself and through learning. The table on page 4, produced by the International Energy Agency, shows that for every doubling of capacity installed – which can be relatively small in absolute terms for a young industry – unit costs have fallen between 5% and 20%. This is not necessarily a recipe for success. It has to be the right fuel technology that is scaled up. Some of the unit cost reductions in these existing fuel technologies came from technological progress. Not all fuels will have this potential. Another key lesson from history is that governments have had many failures in 'picking winners'.

Working with nature to reduce costs and improve sustainability

While the industrial technologies needed to convert current biomass sources into fuels shows varying degrees of promise to ride a lower cost curve to affordability, there is an even greater potential for improvement when looking at emerging biomass technologies. The biological and agronomic science behind an entire portfolio of next generation biomass types is a relatively un-explored domain of lower cost, higher sustainability fuels.

Significant research on identifying and further developing new sources of biomass for energy has only emerged in the past decade, and the potential for dramatic reductions can be expected. Past biological improvement achievements coupled with new technology tools in the ability to achieve biomass improvements, suggests clear opportunities are ahead of us. Much of the overall cost and sustainability of biomass fuels depends on the biomass itself, not the conversion step into fuels: in the end, it's all about the biomass.

Previous generations of biomass fuels were based on crops optimised for food production and involved very high levels of inputs which characterised the mid-20th century approaches agricultural improvement – more water, more arable land, and more petroleum-based fertiliser. The 21st century brings about significant constraints on the continued availability of those inputs. However, these constraints are driving a significant amount of new investment into biomass sources for energy which can thrive in such constrained conditions. Just as many plants respond favourably to stressors, so too are the scientific and commercial research and development communities responding this new 21st century agronomic environment. High sustainability factors and lower cost fuels are seen by some as negatively correlated – i.e. high sustainability means expensive. This relationship is changing and the drivers are new biomass approaches which use sustainability as an enabling design tool rather than a barrier to be overcome.

A pluralistic approach

The answer in today's early stage development in aviation biofuels must be to take a pluralistic approach. Private venture capital is already providing some support to some of what currently appear to be the most promising fuel technologies. Others, such as those based on algae feedstock which look promising but still require major research and development, have received some support from governments. But the one or several biofuel technologies that will succeed may still be in the laboratory. Research and commercialisation funding is required for a range of potentially successful biofuel technologies, from which a winner, or winners will emerge.

It is possible that a commercially viable aviation biofuel will emerge, unaided by government support, from the private sector. However, despite impressive progress in early stage development, there is little sign of this happening at commercial scale.

There is still a considerable way to go before aviation biofuels become economically viable. Given the importance of decarbonising the air transport sector there is a strong case for government support to accelerate the scaling up of this young aviation biofuels industry, to bring forward the date when these new fuels become economically viable.

→ CASE STUDY

Local fuel for local flights in one of the fastest-growing markets

A number of initiatives are currently aimed at developing a sustainable aviation fuel industry in China. Boeing and PetroChina Company Limited are leading a thorough evaluation of the potential for establishing a sustainable aviation biofuels industry in China. The project will look at all phases of aviation biofuel development including agronomy, energy inputs and outputs, lifecycle emissions, infrastructure and government policy support. Other United States participants include Honeywell's UOP and United Technologies Corporation, while Chinese participants include the Civil Aviation Authority of China, the State Forestry Administration, and Air China.

In addition, Boeing and the Chinese Academy of Science's Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT) are collaborating on algae-based aviation biofuel, developing algal growth, harvesting and processing technologies. The Joint Laboratory for Sustainable Aviation Biofuels is located in Qingdao and managed by Boeing Research and Technology China and QIBEBT, and has a strong emphasis on commercial applications.

Lastly, Air China and Boeing have planned two significant flights using regionally sourced biofuel. The inaugural Chinese biofuel flight, powered by sustainable fuel produced from Chinese jatropha oil, will demonstrate the potential for a domestic supply chain in China. PetroChina, Honeywell's UOP and Pratt & Whitney are also partners in this effort. A second, trans-Pacific flight will demonstrate and celebrate international collaboration on biofuel development.

→ **CASE STUDY**

Born in the USA

If there is one word that has really signified the work done so far to bring aviation biofuels to life, it is 'collaboration'. The different players in the aviation industry are used to working together for common operational goals, but the emerging world of aviation biofuels has introduced airlines, manufacturers and airports to a completely new set of partners – fuel supply chains, the agricultural community and a wider range of government agencies.

As one of the founders of the Commercial Aviation Alternative Fuels Initiative (CAAFI®) is fond of saying, "another way of looking at the challenges we face is to see them as opportunities for excellence." This attitude has been a driving force of the CAAFI coalition. Co-founded in 2006 by the United States Federal Aviation Administration (FAA), Air Transport Association of America (ATA), Aerospace Industries Association (AIA) and Airports Council International North America (ACI-NA) at a meeting held in The Boeing Company's headquarters, this coalition's aim is to make commercially viable, environmentally friendly alternative aviation fuels a reality. Its step-wise approach has been to identify the challenges to the deployment of such fuels and to take them on, either directly or by working to help leverage the efforts of others toward the common goal.

Indeed, tremendous progress has been made toward commercial deployment of sustainable alternative aviation fuels in the United States by pulling together the various interested stakeholders – aviation fuel users including commercial airlines and the US military, fuel producers, airports, airframe and engine manufacturers, government agencies with remits related to aviation or alternative fuels more generally and universities – and coordinating and combining their initiatives. Although the coalitions and stakeholders go beyond CAAFI, this organisation serves as an 'umbrella group' for the various US activities, helping coordinate a range of actions. CAAFI is organised into four teams, each dedicated to 'opportunities for excellence' in the areas that otherwise might present obstacles to sustainable alternative aviation fuels:

- research and development;
- certification and qualification;
- environmental demonstrations; and
- the business case.

A look at each of these areas shows progress made and remaining opportunities that will benefit from further collective action.

Research and development

Many commentators have remarked about how far aviation alternative fuels have come in such a short time. That such fuels are 'real' has been made clear by the many and successful test flights and rig tests that have been conducted, using a variety of fuels and feedstocks. This success can largely be credited to two factors, the shared vision that aviation alternative fuels need to be interchangeable with today's petroleum-based fuels and focused research, development and testing of fuels around that vision.

CAAFI determined early in its inception that replacing aircraft and aircraft engines to accommodate new fuels would be cost-prohibitive, as would having to put in place wholly separate fuel storage and delivery systems at airports. The US military came to the same conclusion. Thus, commercial and military stakeholders in the US have largely focused their efforts on alternatives that can be 'dropped-in' to existing infrastructure, so-called 'drop-in' fuels. This focus has given 'drop-in' alternatives priority in nearer-term research and funding, with alternatives that would require new aviation architecture – such as hydrogen – being addressed in the longer term research projects.

With the US Air Force goal to have one-half of its jet fuel nonpetroleum-based by the year 2016 and the US Navy goal to supply 50% of its total energy consumption from alternative sources by 2020, the US military services have undertaken significant activities in research and development and fuel approval and deployment. Also, the FAA has dedicated some of its research dollars under the Continuous Lower Energy, Emissions and Noise (CLEEN) programme for research and development of aviation alternative fuels, while US engine and airframe manufacturers have undertaken significant testing, in addition to that done by fuel producers. To allow researchers, fuel producers and potential users to have common understandings of where a particular alternative is in its development and help coordinate development efforts, the CAAFI coalition developed a fuel readiness level (FRL) framework tool. Covering fuels from concept through full commercialisation and identifying the criteria and requirements the fuels must satisfy, this tool also helps determine when a particular alternative is sufficiently beyond the research and development stage to proceed to certification and qualification.

Certification and qualification

Any alternative jet fuel must satisfy the regulatory and standards-making organisation specification requirements for jet fuel. In the United States and much of the world, the recognised jet fuel specification is set by ASTM International. Until very recently, ASTM D1655, 'Standard Specification for Aviation Turbine Fuels', was the only ASTM jet fuel specification. Based on a process forwarded by CAAFI stakeholders, an ASTM research report assembled under the supervision of the Emerging Turbine Fuels subcommittee, and rigorous review by engine companies and other experts, ASTM approved D7566, 'Aviation Turbine Fuel Containing Synthesized Hydrocarbons'. This specification allows for alternatives that demonstrate that they are safe, effective and otherwise meet the specification and fit-for-purpose requirements to be deployed as jet fuels, on a par with fuels under ASTM D1655.

The initial issue of D7566 enables use of fuels from the Fischer-Tropsch (FT) process in up to a 50% blend with conventional jet fuel. FT fuels can be generated from a variety of feedstocks, including biomass (biomass to liquid) and natural gas to liquid, in addition to coal to liquid and combinations thereof. Most critically, however, the ASTM D7566 specification is structured, via annexes, to accommodate different classes of alternative fuels when it is demonstrated that they meet the relevant requirements. One such annex is for hydrotreated renewable jet (HRJ) blends (also referred to as bio-derived synthetic paraffinic kerosene, or 'Bio-SPK'), with other

alternatives (such as hydrolysis / fermentation, lignocellulosic bioconversion, pyrolysis / liquefaction) to follow as data from technical evaluations is obtained.

Environment

A significant driver for the deployment of alternative aviation fuels is the benefit they may bring in reducing emissions from aviation, whether associated with local air quality or global climate change. CAAFI and other groups have made significant progress in confirming the methodologies for lifecycle analysis of alternative aviation fuels and in supporting or performing case studies that use these methodologies. Two cooperative US initiatives have produced significant work product in this regard. For example, an interagency working group led by the US Air Force and coordinated with CAAFI stakeholders developed critical guidance on how to perform lifecycle emissions analysis for aviation fuels. Working with that, researchers as the Massachusetts Institute of Technology, funded under a partnership supported by many CAAFI stakeholders, produced a comprehensive case-study analysis on potential alternatives. This work, as well as work on broader sustainability criteria, is being further advanced by the CAAFI Environment Team under two work streams that are expected to further firm up environmental guidance that may help fuel purchasers incorporate relevant environmental criteria into future purchase agreements.

Business case

Fuel costs are a significant portion of an airline's operating costs – in many cases, the greatest portion. Given that airlines typically generate razor-thin profit margins even in good years – and incur substantial losses in bad years – any fuel used by the airlines must be competitively priced and reliably provided. US aviation stakeholders are working hard, through CAAFI and other coalitions, to help make alternative aviation fuels readily available and price-competitive.

A key aspect to ensuring availability of these fuels is sending market signals that aviation is a ready, willing and optimal buyer. One initiative in this regard has been the strategic alliance between ATA and the US military, through its procurement arm (the Defense Logistics Agency). The US Air Force consumes about as much jet fuel in a year as a mid-sized airline would. However, the combined demand of US commercial airlines and the US military amounts to more than 1.5 million barrels of jet fuel per day, a volume that is more attractive to fuel providers who also may be considering supplying other fuel users, such as ground transport. The strategic alliance allows for pooling this demand and the consideration of joint purchasing agreements, but also provides another mechanism for sharing experience on fuel certification and environmental impacts. Already, two pre-purchase agreements for aviation biofuels have been announced between US commercial airlines and alternative fuels producers, with more commercial and military announcements in the works.

A key to helping make alternative aviation fuels price-competitive with petroleum-based fuels is to avail these fuels (and the feedstocks that go into making them) of government and other incentive programmes. In July 2010, the US Department of Agriculture (USDA), ATA and Boeing signed a resolution memorialising their commitment to work together on a 'Farm to Fly' initiative "to accelerate the availability of a commercially viable sustainable aviation biofuel industry in the United States, increase domestic energy security, establish regional supply chains and support rural development". This initiative is aimed at helping align US agricultural policy, which includes encouragement for growing energy crops, with the interest of the US airlines and military in sustainable alternative aviation fuels. Issues such as availability of crop insurance, means of reducing costs of energy crop feedstocks and bio-refinery opportunities are among those coming out of this initiative.

International benefits

While CAAFI started as a US initiative, it now has over 300 stakeholder participants from all around the globe, allowing for shared experiences and further leveraging. Not only will many of the developments in the US bring benefits to the global market, but developments elsewhere will further stimulate US initiatives. The key will be to continue to look for opportunities for excellence together.

→ CASE STUDY

Collaborative action in the Pacific Northwest

Sustainable Aviation Fuels Northwest (SAFN) is a regional initiative in the Pacific Northwest of the United States sponsored by Alaska Airlines, The Boeing Company, the Port of Seattle, the Port of Portland, Spokane International Airport and Washington State University. These organisations have convened a diverse regional stakeholder group to determine the feasibility of developing regionally sourced, sustainable aviation fuels in the Pacific Northwest.

This regional assessment is being facilitated by the non-profit Climate Solutions, which has coordinated a series of workshops spread over nine months and is working on a report reflecting the consensus recommendations. The workshops, data analysis, and ongoing working groups are contributing to a final report which will:

- *identify major barriers, opportunities and options for development of a sustainable aviation fuels industry in the Northwest;*
- *examine and analyse potential feedstock pathways available in the Pacific Northwest to supply sustainable aviation fuels, including oilseeds like camelina, forest residual waste, algae, waste materials and sugars;*
- *clarify the importance of evaluating and demonstrating the sustainability of biofuel production and include a framework for applying sustainability principles;*
- *illustrate potential trade-offs among various outcomes and alternative pathways; and*
- *evaluate the potential logistics and compatibility issues related to the introduction of sustainable biofuels at regional airports.*

Through this process, SAFN stakeholders will identify a set of "flight plans" to create Northwest supply chains for sustainable aviation fuels. Importantly, the project will look at how the biomass and refining process can be used to supply both biofuel for use in aircraft and biodiesel for use in ground-based vehicles, ensuring that the most use can be made from the biomass possible. The stakeholders represent a wide range of interests, including aviation leaders, biofuel developers, growers, forest managers, federal, state and local governments, industry associations, environmental and conservation groups, universities and industries.

→ **CASE STUDY**

Plan de vuelo hacia los biocombustibles sustentables de aviación en México

Expertise in aviation biofuels is being fostered all over the world. In Mexico, a government agency which provides jet fuel to the nation's airports is taking a lead role in fostering this important green growth opportunity. The challenges are the same as for a lot of nations with similar diversity of landscapes and economic profiles, but it has to be said that with the Plan de Vuelo, Mexico is engaging in an impressive display of 'joined-up thinking'.

The Mexican Federal Government, following the objectives that the international aviation industry has established, has started an ambitious programme of action to ensure the development and viability of sustainable aviation biofuels in the country. This comprises an active participation within the ICAO framework via the Dirección General de Aeronáutica Civil (DGAC, Mexican Civil Aviation Authority), as well as the design and implementation of a comprehensive far-reaching road-mapping exercise called the "Flight Plan Towards Sustainable Aviation Biofuels in Mexico", coordinated by Aeropuertos y Servicios Auxiliares (ASA, Airports and Auxiliary Services).

ASA is the sole supplier of jet fuel in Mexico, responsible for all into-plane operations and the management of over 60 fuel farms in the Mexican airport network. In the global context, Mexico represents 2% of the world's jet fuel market, as it provides close to 10 million litres a day for approximately 2,300 flights comprising what could be termed a "small but big market".

When considering its position along the supply chain of aviation fuel, being the last link gives ASA a unique viewpoint from which it can act as the promoter and catalyst of the budding aviation biofuel industry in Mexico. ASA's position as an intermediary client between PEMEX (Mexico's state-owned oil company) and the airlines, gives it an exceptional lever with which to pull all interested stakeholders along the aviation biofuel value chain.

The flight plan

The main idea behind the Flight Plan Towards Sustainable Aviation Biofuels in Mexico is to analyse the existing and missing links in the supply chain for sustainable biofuels. It is similar to a road-mapping exercise in that it looks into the market drivers, the associated products and services, and the technologies that could help an aviation biofuel industry get off its feet. The main objectives of the Flight Plan are to diagnose the state in which the different parts of the supply chain are, to involve all the interested stakeholders, and communicate to society at large the benefits that aviation biofuels can bring.

A series of workshops for the Flight Plan were designed using a schematic view of the supply chain. Given that the premise of biofuels is that they will lower the carbon footprint in comparison to fossil fuels, the first workshop was organised to look into the general problematic of this type of energy, and specifically to the sustainability issues that need to be observed across the supply chain.

The other workshops were organised so that all the points across the supply chain could be analysed, including:

- raw materials and extraction;
- infrastructure and refining; and
- financing, legislation, logistics and distribution.

A two-pronged approach was followed in which specific subject matters were addressed, as well as looking into cross-sectional or longitudinal themes that are present across the supply chain. The exercise started with a contact list of around 100 people, and as it progressed, it grew over 10 times to a network of over 1,000 stakeholders. With an average audience of 120 persons throughout this project, all the principal actors, as well as governmental, financial, private, academic and research institutions, gathered in the same forum sharing their ideas, proposals, experience and commitment in this huge global challenge. It is important to note that in the design and implementation of the Flight Plan, ASA received the support of several organisations, especially from The Boeing Company and the Roundtable on Sustainable Biofuels (RSB).

Analysis of the supply chain

Mexico is the fourth most diverse country in the world with 5,870,921 hectares with high productive potential. The analysis of the different feedstocks resulted in several candidates that could be developed into second generation sources: jatropha, castor, salicornia, agave and algae. Most of these plants are indigenous to the country and have been harvested for many generations as they grow in the wild in many regions of the countryside. In fact, there is advanced biofuel feedstock production in a number of Mexico's states, taking into account local species and most suitable crops for each growing condition.

The production of vegetable oil is an important topic, since much of the installed capacity is underused. For many years, the vegetable oil industry has been in on standby, as many of the usual vegetable oil generating feedstocks have not been produced in Mexico for some time due to lack of water or adequate land. In the end, the oil extracted to produce a biofuel is independent of the source, so the promotion of viable second generation sources is critical. One consideration is the use for the residual biomass that is produced, and the secondary markets where it can be utilised. There is also another important issue to be considered – the current crude vegetable oil cannot meet the current specification for the refining process, and so pre-refining is needed.

In terms of the refining industry, Mexico has historically been handicapped in the production of the necessary fuels to feed the requirements of its economy. However, in the production of jet fuel, the country has always been self sufficient. It is in the interest of ASA to guarantee the production of aviation biofuels, so that Mexico has the capacity to meet its future internal demand. ASA has, therefore, found an economic case for planning specific refining capacity. In fact, by 2020 with the right funding structure in place, it is expected that up to four aviation biofuel specific refineries will be operating in Mexico, generating 800 million litres of sustainable aviation biofuel. There are important legal obstacles that need to be overcome, as some of the by-products of the refining process can only be managed by the national oil company – PEMEX. Beyond this, the current biggest jet fuel market in the world is just north of the country, so any surpluses that are produced will certainly find willing buyers.

Towards the end of the supply chain, the point where the blending of the product will take place will depend on the capacity of ASA's installations, as dedicated infrastructure needs to be considered. This will not be a problem in the beginning, but it is bound to show some constraints as the industry develops and as the quantities of aviation biofuel that need to be blended become significant. The storage of the product has also shown some challenges, as the difference in densities between the biofuel and the fossil fuel have to be taken into account.

Longitudinal analysis

As part of the analysis of the supply chain, consideration was given to several themes that are present across the specific stages. These include the financial, legal, and sustainability perspectives.

From the financial perspective, several institutions were invited to give their ideas as to how the markets would react to the measures that are being implemented across the globe, such as the European Union's Emissions Trading Scheme, or the Clean Development Mechanisms promoted by the UNFCCC. The impacts of such measures are to be an integral part of the financial viability of these types of fuels.

The legal perspective was explored to look into the different clauses of Mexican law that could have an impact in the development of this industry. The Mexican Constitution has a legacy of stringency with respect to energy created from fossil fuels, but there are new laws covering the growth of bioenergetics that show promise, which are still in the advancement stages.

The sustainability perspective was addressed from the viewpoint of the framework provided by the Roundtable on Sustainable Biofuels (RSB). The twelve principles were analysed in detail, and the parallels with the Mexican environmental law were put into perspective.

Next steps

The Flight Plan Towards Sustainable Aviation Biofuels in Mexico has proved to be an invaluable exercise to identify the existing and missing links along the value chain of this new type of energy.

As ASA works on putting together the pieces of the puzzle to define the successful path Mexico will be following in the next few years, the results that will benefit Mexican society, such as the reduction in greenhouse emissions, the promotion of agriculture in marginal land, new jobs, and a major boost for a new industry, are well underway.

New lines of research have emerged and the challenge is to find the necessary funding to pursue them. This, together with the implementation of the defined action items are the necessary next steps to follow so that a necessary aviation biofuel industry is established in Mexico.

→ CASE STUDY

Brazilian Alliance for Aviation Biofuels

The Brazilian Alliance for Aviation Biofuels (Aliança Brasileira para Biocombustíveis de Aviação – ABRABA) was created in May 2010, with the objective of promoting public and private initiatives seeking development of sustainable aviation biofuels with positive carbon lifecycle and certification according to local and international fuel standards.

Founding members of ABRABA include members from aviation, fuel technology and agricultural backgrounds: Algae Biotecnologia; Amyris Brasil; Brazilian Association of Jatropha Growers; Aerospace Industries Association of Brazil; Azul Linhas Aéreas; Curcas Diesel Brasil; Embraer; GOL Linhas Aéreas Inteligentes; TAM Linhas Aéreas; TRIP Linhas Aéreas; and the Brazilian Sugarcane Industry Association (UNICA).

ABRABA will act as a flagship institution integrating the efforts of different players and will support the use of sustainable biofuels as one of the key growth factors for the aviation industry in a low carbon economy. Integrating the Brazilian renewable fuel experience and capability with aeronautical technology expertise, it will foster further economic and social development, as well as significant contribution to environmental protection.

For more information, visit the ABRABA website: www.abraba.com.br

→ COLLABORATION

Pure Sky in Germany

German airline Lufthansa will be undertaking the first long-term trail of biofuel use in daily commercial flights on an Airbus A321 between Hamburg and Frankfurt for six months in 2011. This city-pair flight will allow the industry to study long-term aspects of biofuel use and supply. The project team includes research institutes such as Bauhaus Luftfahrt and DLR and is backed by the German government within the framework of its aviation research programme.

→ **CASE STUDY**

Waste not, want not

Biofuel does not always come from crops. In innovative projects that solve several problems at once, British Airways and other airlines have formed relationships with a company which will produce large amounts of aviation biofuel by processing municipal waste – reducing the industry's dependence on fossil fuels and at the same time reducing the amount of waste in landfills.

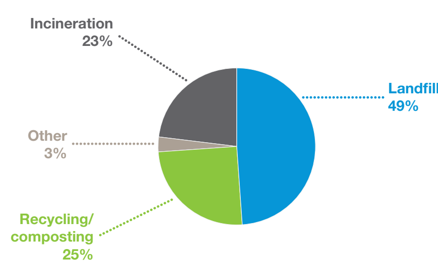
The British Airways and Solena partnership was formed in 2009, when the two companies agreed to work together to develop a unique project for London. Solena, a renewable energy technology company based in Washington DC offered a pathway to sustainable aviation fuels by converting waste biomass into fuels, renewable energy and heat. Although at the time, many biofuel demonstration flight trials had taken place, a full commercial-scale facility for renewable jet fuel had not been constructed. British Airways believes that sustainable fuels offer a unique opportunity for aviation to decarbonise over the short-medium term.

The consumption of jet fuel represents 99% of British Airways' carbon footprint and while the airline continues to implement sustainable practices in other aspects of its business, a main focus now is on the jet fuel that powers aircraft and emits large volumes of greenhouse gases. This is the area for change that offers both the biggest opportunity and challenge. British Airways has an ambitious target to reduce net carbon dioxide emissions from its business by 50% by 2050. It is hoped that renewable sustainable fuels will help to achieve this goal.

The potential for releasing the energy locked up in the UK's waste has been a priority for some time. The UK Department for Environment, Food and Rural Affairs (DEFRA) has a waste strategy for England which says: "recovering energy from waste which cannot sensibly be recycled is an essential component of a well-balanced energy policy and… [DEFRA] expects energy from waste to account for 25% of municipal waste by 2020/21."

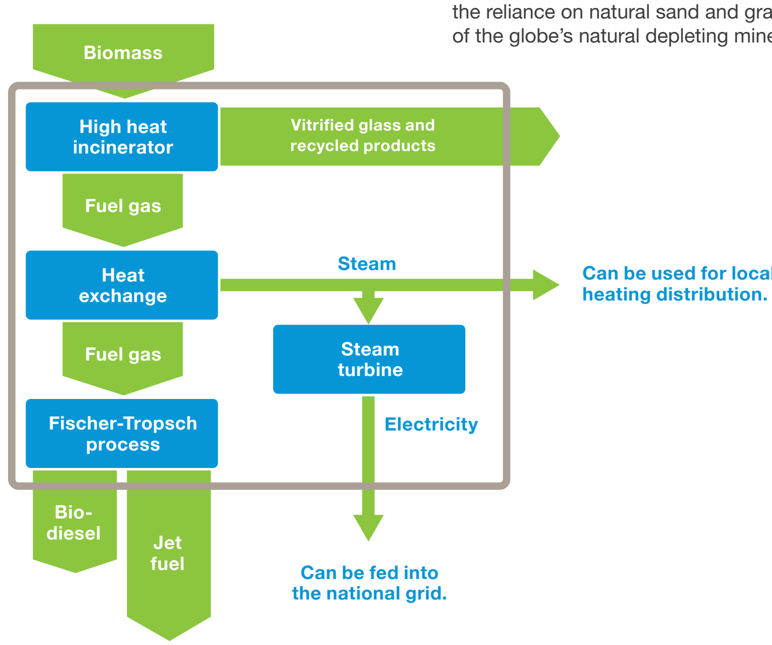
Waste is a significant problem for London, where almost half the city's four million tonnes of municipal waste is sent to landfill, often transported long distances to the disposal site. The Greater London Authority sees great potential in recovering energy from waste and the Mayor proposes a zero waste to landfill target by 2025.

Breakdown of London's municipal waste management methods in 2008/9



The technology

Solena's patented plasma technology is able to convert all forms of biomass into clean renewable energy. Operating at very high temperatures, the system can convert virtually any type of organic material, including waste (e.g. food waste from households and businesses) agricultural and forestry residues, into energy.



The technology is "fuel flexible" so as a thermal conversion platform it can convert low-value hydrocarbon-bearing biomass into a renewable biosynthetic gas (or "BioSynGas"). Planned input capacity for the plant is 500,000 tonnes of waste per year.

Linked to a Fischer-Tropsch unit, the BioSynGas is then converted into biofuels to produce 1170 barrels of aviation biofuel and 630 barrels of bionaphtha per day. Using GE power generation systems, the Solena Plant will produce 20 MW net of green renewable power, which can be sold to the local electricity supply grid.

Excess steam may be produced and utilised in a district heating system. Thus, the plant can benefit its neighbours and have a major effect on CO_2 and greenhouse gas reduction.

The process generates no harmful pollution or toxic ash. The only waste by-product is an inert glass-like material, which is an ideal alternative building aggregate, thus reducing the reliance on natural sand and gravel – one of the globe's natural depleting mineral assets.

What makes this project different?

A number of energy-from-waste projects are being developed in the UK at the moment. This one is different for a number of reasons:

- It is not a conventional waste to energy facility, a chemical plant or a refinery. It is a clean renewable next generation aviation biofuel production facility processed from waste and biomass waste.
- The fuel will have low lifecycle greenhouse gas emissions – up to 90% less than the emissions associated with fossil kerosene.
- The end fuel will be cleaner burning than kerosene (zero sulphur and low aromatic content produce less soot and fine particulates), providing air quality benefits when the fuel is burned.
- A zero waste philosophy means that all materials are recycled, conversion of carbon-based materials is in excess of 99%, there is no bottom ash or fly ash and non-carbon based materials are converted into vitrified slag for use in the construction industry.
- Gasification and Fisher-Tropsch technologies are proven processes being employed worldwide. Solena is developing similar plants in the US States, as well as in other countries. Importantly, the Solena / British Airways partnership is providing the first such plant to produce biofuel in Europe.
- British Airways will directly use the aviation biofuel and is moving into a contractual relationship to purchase the fuels produced.
- It will be a world-class development and the first of its kind in Europe. The end product is a real alternative to fossil fuel for the aviation industry and thus has a long-term viable future.
- Innovative design and technology means the plant will be energy self-sufficient and sustainable in its own right.

The next steps

The project partners plan to locate the facility in East London, close to the source of the waste and close to British Airway's operations in the South East (the nearest airport is London City, from which British Airways runs both short- and long-haul services). During construction, the project will generate around 1,000 jobs in London. From 2014, when the plant is in full operation, 200 permanent jobs will be created. This will be the first development of its kind in Europe, and should provide a proven pathway for a number of other global cities to generate valuable resources from waste.

At the time of this publication going to press, Solena had already signed biofuel plant initiatives with British Airways, Qantas and Alitalia airlines.

→ CASE STUDY

A road map for sustainable aviation fuels downunder

In Australasia, the Sustainable Aviations Fuels Road Map project has been developed in collaboration with the Australasian section of the Sustainable Aviation Fuel Users Group (Air New Zealand, Boeing, Qantas, and Virgin Blue) together with the Defence Science and Technology Organisation. The project is being coordinated by Australia's national science agency, the Commonwealth Scientific and Industrial Research Organisation. SAFRM is a comprehensive regional assessment, examining all phases of developing a sustainable biofuel industry, including biomass production and harvest, refining, transport infrastructure and actual use by airlines. Participants are working to identify the barriers, opportunities and implications of producing sustainable bio-derived jet fuels at scale, including:

- *commercial viability;*
- *environmental sustainability;*
- *alternative biomass feedstocks suitable for growing in that particular region;*
- *key policy, commercial and research actions needed.*

This assessment draws on the diverse expertise of a broad range of stakeholders to map out future scenarios, including biomass producers, refiners, airport operators, environmental and government organisations, airlines, academic representatives, and airline and engine manufacturers.

→ COLLABORATION

Sustainable Bioenergy Research Center

This consortium in the United Arab Emirates – involving Boeing, Etihad Airways and Honeywell's UOP, and hosted by Masdar Institute of Science and Technology – drives technological development in arid land and saltwater-tolerant terrestrial biomass.

→ **CASE STUDY**

A massive opportunity lies just off shore

Sometimes, the biggest breakthroughs come from surprising places. Around the world, the aviation industry, academic institutions and biofuel companies are working together to accelerate the development of one of the most promising sources of aviation biofuel in the long-term – the microscopic and ubiquitous plants that can be grown almost anywhere known as algae.

It is widely agreed that the contribution of fossil fuels to global climate change is a major issue that industry and society has to urgently address. Biomass from micro algae has been demonstrated at laboratory scale to be a viable source of low carbon bio-fuel for aviation. The challenge ahead is to industrialise this process at a very large scale so that its outputs can begin to make significant contributions to global aviation fuel needs. And yet the demands on scarce land and fresh water from aquatic biomass cultivation must be kept to an absolute minimum or avoided altogether.

The Sea Green project is a near-shore ocean-based facility for the sustainable production of large volumes of biomass for aviation biofuels. It is designed to use the expanse of the world's near shore oceans to rapidly grow micro algae as biofuel feedstock at a faster rate than any other initiative and capture CO_2 from the atmosphere and seas at the same time. The Sea Green concept would envisage very large floating structures to be placed in the ocean close to shore on which the cultivation of micro-algae would occur. This can be done in an environmentally-friendly, sustainable facility with a negative carbon mechanism that does not compete with agricultural land, does not require fresh water and does not damage the environment.

Once the micro-algae have been cultivated, they will be sent for processing much like any other biomass on land.

The benefits of moving off-shore

As a project, Sea Green is unique in combining technologies for very large floating structures with microalgae cultivation, delivering major advantages when compared to conventional land-based aquaculture. The use of an off-shore facility would mean higher biomass production and revenues using lower energy because biomass movement is achieved by harnessing ocean currents. The technology can be scaled up or down very easily, to provide for local fuel needs. And, because it can use convenient ocean, sea or even suitable lake locations, there is no requirement to use scarce agriculture land or fresh water resources.

It is estimated that the concept will be able to produce 35 times more biomass than agriculture energy crops, twice as much biomass as land based aquaculture and additionally is more energy efficient through harnessing the agitation and nutrient transport benefits of ocean waves and currents. Sea Green also mitigates against many of the recognised issues arising from the conventional land-based methods of producing biomass. The advantages arise from four potential scenarios:

- securing locally produced biofuel as a strategic asset for fuel source diversity;
- selling harvested biomass to be processed into biofuels or speciality products;
- sharing intellectual property rights revenue from licensing the Sea Green design family;
- reducing pressure on scarce land and fresh water resources.

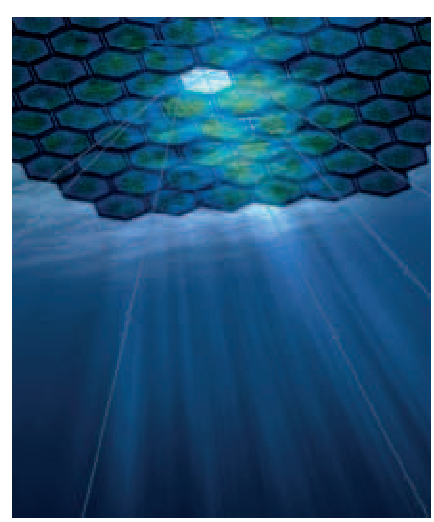
Bringing the concept to life

To make this vision a reality requires a staged process of testing, scale up, pilot plant and production plant construction with all key stakeholders actively engaged from the outset. The stakeholder engagement is being achieved by the formation of a Sustainable Use of Renewable Fuels (SURF) consortium that will take a structured approach to addressing five major considerations for the successful use of biofuels from a renewable source like micro-algae. These will include: environmental impact; processing; capacity and distribution; commercial and legislation and regulation. Specific studies will look at future sustainability modelling and environmental lifecycle assessment. Formation of the Consortium was announced at the Aviation & Environment Summit in Geneva in September 2010. SURF is made up of Airbus, British Airways, Rolls-Royce, Finnair, Gatwick Airport, the International Air Transport Association and Cranfield University.

The Sea Green project is undertaking staged scale-up and industrialisation of a process for large-scale floating biomass production from micro-algae. Modelling and front end engineering design activities have been completed by Cranfield University.
The sub-sequent staged process has the following steps:

- laboratory testing at the 1-litre to 10-litre scale to define overall performance parameters;
- testing in a small-scale pilot facility on the Cranfield University campus which is growing and processing algae for biofuels at the 1000-litre scale;
- production of quantities of aviation biofuel at approximately 10,000-litre scales for its use as commercially available test samples for engine testing;
- development and construction of a larger scale production facility to initially meet the needs of a specific aviation market sector – say for business aviation.

It is envisaged that the first commercial quantities of products from Sea Green will become available within three years.



The six easy steps to growing a viable aviation biofuels industry

Many of the technical hurdles facing aviation in its move towards sustainable aviation biofuels have now been overcome and much of this work has been achieved within the industry. Now, commercialisation and scaling up of the supply of aviation biofuels is the most important task.

As shown in the selection of case studies in this publication, the industry has been forging ahead with pilot projects in a number of countries worldwide. But airlines and the rest of the industry cannot do it alone – political support and financial investment will have to come from a number of stakeholders. This section outlines six 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. These steps are presented in no particular order:

1 Foster research into new feedstock sources and refining processes

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. Early generation biofuels used feedstocks derived from food crops such as rapeseed and corn. However, these feedstocks can be used as food for humans and animals, raising important questions about their sustainability. In response to these concerns, the industry is now focused on exploring the use of advanced-generation biofuel sources that are truly sustainable.

Several pathways are being considered for the development of sustainable aviation biofuel and these are illustrated below.

The industry is unlikely to rely on a single feedstock. 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.

Much of the current research and development work on alternative fuels is focused on biodiesel and bioethanol projects for land transport. Ultimately, this will delay land transport's switch to more sustainable energy sources, such as electricity and hydrogen fuel cells.

Policy enablers include establishing funding programmes for academic research through existing or new university, research institution or industrial research projects, broadening or re-focusing university research of biofuels to include aviation-specific projects.

2 De-risk public and private investments in aviation biofuels

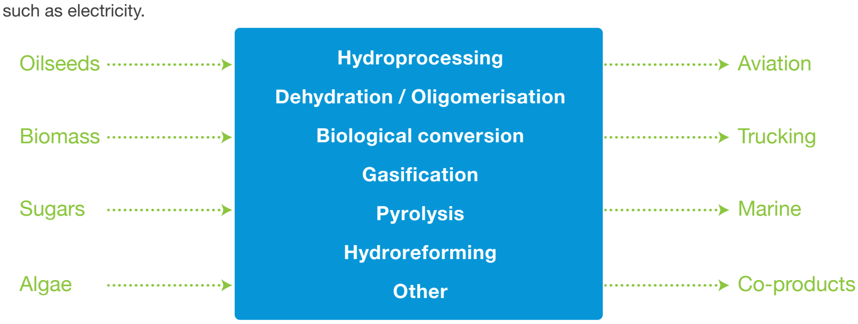
To be economically viable, sustainable aviation biofuel must be priced at a level the market will find acceptable. At present, aviation biofuel is not cost competitive with current jet fuel. However, traditional jet fuel is forecast to become more expensive. By contrast, sustainable aviation biofuel will become less expensive as the industry develops. Policies incentivising biofuel 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 biofuel is gained by examining the cost drivers. For the technology pathway that is nearest commercial viability, it is estimated that 85% of biofuel production costs relate to the cost of feedstocks. As the technology to harvest and process these feedstocks progresses, 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 a few years ago, prices for these feedstock inputs have already dropped significantly. 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 biofuel, 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 production in Europe and the US, which could hamper the establishment of aviation biofuel production.

These incremental upfront capital investment costs are a potential barrier to commercialisation. 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 catalyse establishment of the sector.

Advanced aviation biofuels will come from a range of feedstocks and processing methods. They should be prioritised for aviation and other 'heavy' transport uses over those forms of transport that have alternatives such as electricity.



→ CASE STUDY

A multi-stakeholder approach in Brazil

JETBIO, a Brazil-based company specialising in biofuels projects, is leading the development of an integrated project aimed at producing and supplying sustainable aviation biofuel to airlines. The initiative is supported by TAM Airlines, Airbus, AirBP and Bio Ventures Brasil.

The project addresses the Implementation of a sustainable aviation biofuel value chain, bringing together the key players to foster:

- *jatropha research and development for locally adapted elite cultivars and scale-up;*
- *logistics optimisation;*
- *installation of aviation biofuel production capacity by 2013; and*
- *lifecycle carbon emissions analysis and sustainability studies of the value chain.*

JETBIO has adopted a multi-feedstock approach for aviation biofuel production, focusing on the development of cost-efficient and sustainable sources such as jatropha and sugar-cane derived biomass. In the mid- to long-term, once scale and costs reach adequate levels, these alternatives will gradually replace currently available feedstock.

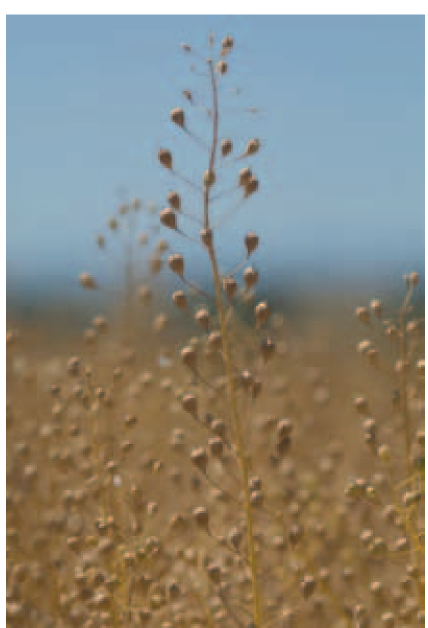
The Southeastern region of Brazil was selected for the construction of the renewable jet unit, as it represents at least 60% of the jet fuel and 40% of the diesel consumption in the country. Furthermore, the region benefits from nation's best logistics and industrial infrastructure. The project aims at starting aviation biofuel production by the end of 2013 to supply initially the São Paulo and Rio de Janeiro airports, from where a majority of international flights operate in Brazil.

3 Provide incentives for airlines to use biofuels from an early stage

If a policy or incentive mechanism is a key part of making renewable energy project economics attractive, changes to these factors pose a risk: a long-term, stable policy regime with a sound legal basis is essential for serious investment to take place.

Unlike some other renewable sectors, sustainable aviation biofuels are not subject to feed-in-tariffs or mandates. The EU ETS is a policy mechanism that may incentivise sustainable aviation biofuel development, but the price of oil is a far greater driver so its impact will probably be limited in the near-term. The market for sustainable aviation biofuels is primarily driven by other factors including reducing dependence on fossil fuels and improving the carbon footprint of the industry. Consequently, sustainable aviation biofuels are subject to very limited policy risk.

Policymakers can foster development of aviation biofuel by recognising the unique role it can have in reducing the aviation's environmental impacts. Aircraft cannot use alternative renewable energy sources available to other sectors such as plug-in, wind, solar or hydroelectric power. Thus, crafting policies that create a level playing field for biofuels vis-à-vis other energy sources, and aviation vis-à-vis other sectors, is a key element in aviation biofuels commercialisation.



4 Encourage stakeholders to commit to robust international sustainability criteria

Sustainability standards are being established that will provide suppliers, investors and customers with clear guidelines as to what is considered to be a sustainable biofuel. For example, in the EU, the Renewable Energy Directive (RED) contains specific criteria addressing this. The Switzerland-based Roundtable on Sustainable Biofuels (RSB) has a sustainability standard developed through a multistakeholder process that ensures the sustainability of production, processing and implementation. 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:

- will not displace, or compete with, food crops or cause deforestation;
- minimise 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; and
- deliver positive socio-economic impact.

As a global transportation sector, aviation needs a harmonised standard to ensure that sustainability criteria are enforceable and equally applied across the industry. A patchwork of standards would inhibit the development of a commercially viable market. While there are myriad standards in place, both regulatory and voluntary, a critical element will be for aviation biofuel stakeholders to enable greater cooperation between standards to increase transparency, decrease the cost of compliance, increase end-user visibility to the biomass, and increase the incentives for next generation fuel pathways. It is also vital that a unified accounting structure be established to verify the origin and sustainability credentials of biofuels for aviation.

The development of an accepted set of globally harmonised standards will help ensure that investment is directed at biofuels that meet acceptable sustainability criteria, thus minimising this form of risk. Criteria need to be mutually recognised 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.

5 Understand local green growth opportunities

Sustainable aviation biofuel doesn't only bring environmental benefits for aviation, it can also foster the development of a new industry. Given the diversity of feedstocks that aviation is considering, there are few places on earth 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 smaller scale biofuel facilities in cities utilising municipal waste.

By bringing the aviation industry, government, biofuel, agriculture and academic expertise together, analyse the optimum opportunities that exist in your country for aviation biofuel production including the most effective feedstock sources and infrastructure requirements. A number of regional development banks are also working on ways to encourage the process. The contacts at the back of this publication may provide advice for how to get this process started.

6 Establish coalitions encompassing all parts of the supply chain

Experience has shown that there are many benefits to be gained from collaboration across the various stakeholder groups involved in all aspects of aviation biofuel production and use. These groups can bring together parties that have not traditionally needed to work together, such as:

- Airlines, airports, aircraft and engine manufacturers;
- Academic institutions;
- Fuel refining companies;
- Agricultural companies and farmers groups;
- Local, regional and national Departments of Agriculture, Defence, Transport, Economic Development and Enterprise;
- Regulators – aviation, transport and agricultural;
- Chambers of commerce and industry;
- Environmental and sustainable development NGOs.

Throughout this publication are examples of stakeholder-oriented processes, all of which are groups of regional and national stakeholders, who have convened to work through the sustainability, supply, investment and long-term planning issues and maximise the opportunities within their respective regions.

Within coming years, many significant commercial, policy and sustainability outcomes will result from such comprehensive regional stakeholder processes. These processes serve to enable commercial parties, while also giving confidence to governments and civil society organisations that sustainable aviation fuels efforts are following a contemplated path.

Those seeking to better understand potentials for this industry should engage with the processes identified in this publication to understand next steps in each region.

→ CASE STUDY

Testing on a range of aircraft

A number of test and demonstration flights have taken place on commercial jet aircraft in the past few years, but none yet on turboprop regional aircraft. Canadian aircraft manufacturer Bombardier is part of a group of companies working towards demonstrating the use of camelina seed oil in a Q400 aircraft in 2012.

The project is being supported by Sustainable Development Technology Canada, an agency created by the Canadian Government. Each of the partners in the consortium is working on a different aspect of the project:

- *Targeted Growth Canada – leading the consortium and crop optimisation and growth;*
- *Sustainable Oils – pre-refining the camelina oil;*
- *Honeywell UOP – secondary refinery to aviation biofuel;*
- *Bombardier and Pratt & Whitney Canada – technical evaluation;*
- *Porter Airlines – providing the aircraft.*

Camelina provides benefits over traditional petroleum-based fuel because it reduces greenhouse gas emissions by up to 80%, reduces sulphur dioxide and is not competitive with food production because it can be grown in rotation with wheat and on marginal land. The strategic benefit to farmers is that it allows them to drive additional revenue from acreage with a low-cost input crop with two end user markets – the oil for fuel and "meal" for livestock and dairy industries.

The aviation industry has established a plan for reducing emissions. Sustainable aviation biofuels are an important part of that plan and, as you will have seen in this publication, the industry and its partners have made significant progress. There is confidence that biofuels can be a very significant part of every airline's future. From policymakers, the industry is looking for encouragement and the right set of legal, fiscal and policy responses to ensure this exciting new energy stream can bear fruit as quickly as possible.

→ CASE STUDY

First camelina biofuel value chain in Europe

Airbus and TAROM Romanian Air Transport together with a group of key stakeholders have established one of Europe's first projects aiming to establish a sustainable aviation biofuel processing and production capability. The Romania based project aims to provide a biofuel made from camelina as a sustainable substitute to fossil based jet fuel.

The project is developed by a consortium of partners led by TAROM, and joined by Honeywell's UOP, CCE (Camelina Company España) and Airbus. UOP contributes aviation biofuel refining technology and knowledge, CCE contributes knowledge on camelina agronomy, including technologies on camelina growth, agricultural monitoring networks and plant science, and Airbus contributes technical and project management expertise while sponsoring the sustainability assessment and life cycle analysis studies.

The first part of the project is focused on feasibility studies on agricultural, technological and aeronautical development and sustainability assessment.

The project will also assess the existing refining facilities in order to identify the Romanian production capability. The feedstock chosen for this project is the camelina plant due to its energy potential, its rotational crop qualities, its green house gas reduction efficiency and low water requirements. Camelina is indigenous to Romania, it can be readily farmed and harvested by family farmers and has a high quality animal feed by-product.

→ CASE STUDY

First large-scale algae biofuel value chain

Qatar Airways, together with Airbus, Qatar Petroleum, Qatar University Science and Technology Park and Rolls-Royce have come together as partners in the Qatar Advanced Biofuel Platform (QAPB) consortium to develop the first large-scale algae bio-jet fuel value chain in the world.

The first part of the project was a research and technology study on local micro-algae species made by Qatar University and the development of a lab-scale biofuel production facility.

Currently, the project is being developed from lab-scale to the demonstrator-scale. This part of the project will take 18 months to put in place, with a substantial multi-million dollar investment. Importantly, the CO_2 required for the algae growth is being captured from a Qatar Petroleum refinery. The chosen location for the demonstrator plant gives the possibility to scale up to commercial scale once the concept has been proven.

An important part of the project is around knowledge transfer. The knowledge gained from the project will be used by Qatar University in order to develop a bioengineering course.

The QAPB is the first large-scale production of algal feedstock to be transformed into bio-jet fuel in the world.

→ CASE STUDY

Just do it for sustainable aviation fuel: SkyNRG

Following a KLM biofuel demonstration flight in 2009, the airline joined with North Sea Group and Spring Associates to launch SkyNRG. A joint venture with a single mission to make the market for sustainable and affordable aviation fuel. Although all players believe cost will eventually decrease when technology and scale advances, the founding companies realised a 'just do it now' attitude was required to speed up this development. In this light, first commercial volumes are essential in engaging investors, governments, NGOs and customers and to accelerate a market tipping point.

To create these first volumes, SkyNRG has taken a downstream, bottom-up approach and are aggregating demand from aviation players across the world. They literally help 'make' the market by delivering a full 'feedstock to flight' proposition that will help establish green routes across the world, whilst doing everything possible to keep it affordable for the customer by smart supply and partner strategies.

On top of selling and promoting sustainable aviation fuel, SkyNRG is putting a lot of effort in guaranteeing sustainability as they believe it to be the most crucial factor in making this emerging market a success. Next to their Roundtable on Sustainable Biofuels partnership they have also installed an independent Sustainability Board consisting of leading NGO's and scientists advising on all feedstock and technology decisions.

Contacts and further reading

The aviation industry has built up significant expertise in the area of alternative fuels. If you are interested in receiving further information or researching the potential for growing a sustainable aviation biofuels industry in your own country, these organisations may be able to assist.

Airbus
www.airbus.com/innovation/future-by-airbus/alternative-fuel

Air Transport Association of America (ATA)
www.airlines.org/Environment/AlternativeFuels/Pages_Admin/AlternativeFuels.aspx

Aeropuertos y Servicios Auxiliares, an independent agency of the Mexican Government
www. asa.gob.mx/wb/webasa/asa_combustibles

Boeing
www.boeing.com/aboutus/environment/index.htm

Bombardier
www.bombardier.com/en/aerospace

CFM International
www.cfm56.com/cfm-value/environment/alternative-fuels

Commercial Aviation Alternative Fuels Initiative (CAAFI®)
www.caafi.org

Cranfield University Clean Technologies School of Engineering
www.cranfield.ac.uk/aerospace/index.html

Embraer
www.embraer.com/en-US/amb-responsability/Pages/Home.aspx

GE Aviation
www.geaviation.com

International Air Transport Association (IATA)
www.iata.org/whatwedo/environment/Pages/alternative-fuels.aspx

Honeywell UOP
www.uop.com/processing-solutions/biofuels/green-jet-fuel

Pratt & Whitney
www.pw.utc.com/vgn-ext-templating/v/index.jsp?vgnextoid=91a2d544b5ac0210VgnVCM1000004f62529fRCRD

Rolls-Royce
www.rolls-royce.com/civil/customers/fuelling_debate.jsp

Roundtable on Sustainable Biofuels
http://rsb.epfl.ch

Sustainable Aviation Fuel Users Group (SAFUG)
www.safug.org

The links below, and more, can be found at www.enviro.aero/biofuels/reference

Sustainable Aviation Fuels Northwest Project:
www.climatesolutions.org/programs/aviation-biofuels-initiative

Farm to Fly:
www.airlines.org/Energy/AlternativeFuels/Documents/farmtoFlyPresentation071410.pdf

Research and papers on aviation biofuels:
www.climatesolutions.org/programs/aviation-biofuels-initiative/safn-bibliography

Biofuel testing summary report:
www.safug.org/assets/docs/biofuel-testing-summary.pdf

Green Skies Thinking, a report looking at why aviation should be a priority user of biofuels by the UK organisation Policy Exchange:
www.policyexchange.org.uk/publications/publication.cgi?id=129

Report on the lifecycle carbon assessment of camelina:
http://onlinelibrary.wiley.com/doi/10.1002/ep.10461/full

IATA Alternative Fuels Report:
www.iata.org/ps/publications/pages/alternative-fuels.aspx

Report on the lifecycle carbon assessment of jatropha, a Yale University study conducted with funding from Boeing which undertook the first sustainability assessment of jatropha using real world field data from actual jatropha farms. The results on lifecycle carbon assessment are in this abstract:
http://pubs.acs.org/doi/full/10.1021/es1019178

Governments' Unique Role in Sustainable Aviation Biofuel:
www.safug.org/assets/docs/SAFUG_Brochure.pdf

Press report on the lifecycle carbon assessment of biofuels from halophytes:
www.thenational.ae/news/uae-news/environment/plant-seeds-could-produce-jet-fuel

Comparative carbon benefits of using biomass in aviation vs ground transport vs power generation:
www.future-science.com/doi/abs/10.4155/bfs.10.70?journalCode=bfs

American Institute of Aeronautics and Astronautics paper on a bio-SPK:
www.newairplane.com/environment/#/SustainableAviationBiofuel/SustainableBiofuel

ASAs Flight Plan for Biofuels in Mexico:
http://plandevuelo.asa.gob.mx

www.flyonbiofuels.org

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