A lot of hope is being pinned on biofuels such as algae, jatropha and helophytes to provide an environmentally-friendly alternative to conventional fuel in the near future. But is the industry right to think that it is the best end user, or even that cost-effective quantities of certain biofuels can be produced in time to have a significant effect on climate change policies? Jeff Gazzard, **a board member of the Aviation Environment Federation, says the biofuel issue may not be as clear as it seems**

Bio-fuelled or bio-fooled?

The law of unintended consequences

To begin with, a cautionary tale. In May 2008, aviation fuel distributed by pipeline to Birmingham airport in the U.K. was found to be contaminated by biodiesel. Pipelines from oil refineries distribute all types of petroleum products in batches around the U.K., including diesel. This can now contain a biodiesel component as part of the U.K.'s Renewable Transport Fuels Obligation legislation for all road vehicle fuels to contain at least five per cent biofuel from sustainable renewable sources by 2010. This policy has been introduced to help reduce CO_2 emissions from the transport sector as part of the U.K. and Europe's climate change policies and CO_2 reduction targets.

The current content rules for jet fuel limit this type of contamination to less than five parts per million by volume and this incident showed the importance of carrying out post-manufacture testing when the fuel is actually in transit or being stored in the airport pipeline/distribution system. Notes from the Joint Inspection Group (JIG) show that they were aware of this problem in their "November 2007 Bulletin number 15" – the JIG is open to membership from the following categories of interested parties and oversees the U.K.'s aviation pipeline network:

- Organisations with interests in facilities used for the storage and delivery of aviation fuels;
- Professional organisations with similar objectives to JIG;
- Organisations that use aviation fuels or represent airlines or military users;
- Aviation fuelling equipment suppliers, aircraft manufacturers or aircraft component manufacturers.

So the safe level of fatty acid methyl esters (FAME) – the biofuel component in biodiesel – contaminant is currently 5ppm. FAME can have a freezing point that renders them unsuitable for aircraft use and the various high-profile aviation biofuel trials underway now all have an additional high-specification anti-freeze additive component and are being trialled in a variable 10-50 per cent mix with conventional kerosene. They can also degrade seals in aircraft fuel systems and leaks may arise – this is because the aromatic content of this type of fuel is lower than kerosene and can affect the expansion co-efficient of seals, another reason why they are used only in blends with conventional kerosene.

However, the U.K. pipeline network, as this product cross-contamination shows, has supply links to both airports and other end-user storage and distribution points, hence the need for different products to flow through the network at different times. The JIG seems primarily, and perhaps under-

standably, concerned about the resilience of their overall pipeline operations as these two extracts from their documentation show:

"The JIG Product Quality Committee has recently initiated a process with the OEMs and the specification authorities to approve the presence of FAME at levels that will provide optimum flexibility for multi-product pipeline operators involved in the co-transport of biodiesels and jet fuels. It is hoped that this process can be completed without delay to facilitate the implementation of the various renewable transport fuel legislation requirements and help maintain unconstrained pipeline operations."

> **The jury is still well and truly out as to whether either synthetic or biofuels are yet capable of being either entirely fail-safe for aviation use or environmentally sustainable in the longer term.**

And further that:

"Renewable transport fuels legislation around the world is already making an impact on the operation of bulk fuel transport systems and it will likely become of greater significance from early in 2008. Therefore, the JIG PQ committee believes that maintaining procedures that hold trace levels of FAME to the current minimum level of detection (5ppm) are not operationally practical or sustainable in the longer term.

"The industry needs to establish what level FAME in jet fuel affects its suitability for use…the initial test results provide some confidence that trace

The Aviation Environment Federation is a non-profit making environmental association concerned with the environmental effects of aviation. It seeks to promote a sustainable future for the industry, and as a membership organisation provides advice and information to its members.

Photo: Alexander Kolomietz – Fotolia.com

What of next generation biofuels now that oil is around the $50 mark?

2008 was the year that saw aviation take on the problems of future fuel procurement, and it was the year when many large aviation companies started openly talking about a world beyond kerosene, with all sorts of options mentioned. This was of course at a time when oil was marching towards the highs of $147 a barrel. This meant that the long touted biofuel-from-algae price range was suddenly looking very attractive, being as it is within the $75-85 a barrel bracket. This led to investment, aviation companies getting involved and all sorts of breaking news stories throughout 2008.

But then came the collapse of Lehman Brothers, oil fell back to close to $50 a barrel, stock markets plummeted and investment was subsequently reigned-in. With Opec in disagreement about the way forward and the global economy set for a harsh 2009, it is hard to see oil getting close to the $100 a barrel mark within the next twelve months, if not the $80 a barrel mark. So is biofuel development on hold for now? Not one bit of it! The R&D investment may have taken a blow from the economic problems of the west but now there are others with more cash who want in!

levels of FAME up to 100ppm may be acceptable." (Source: JIG Bulletin number 15, November 2007)

The JIG, in light of increasing amounts of FAME in the system, is currently looking to significantly increase the "safe" level of FAME contamination thus:

"JIG also noted the need for an approval of 100ppm FAME in jet fuel and the UK Energy Institute has recently created a joint industry project to pursue this goal." (Source: JIG Bulletin number 16, June 2008)

So, at first sight of the notes of the industry body looking at this problem, we know that the pipeline distribution contamination difficulty at Birmingham airport is confirmed as a result of cross-contamination from biodiesel FAME; the incident showed levels of up to 20 ppm of FAME present in the affected aviation fuel, four times higher than the current 5ppm recommended limit. The JIG group is working with the U.K. Energy Institute to seek approval for a new 20 times higher limit of 100ppm FAME-in-aviation fuel contamination. This goal seems, to the writer at least, to be based upon an assumption of the possible likely future levels of pipeline contamination as quantities of FAME in non-aviation fuels increase over time and the consequent supply difficulties (for example product write-offs, discontinuity of supply, cost implications and so on) rather than a fully risk-assessed safety case for preventing the contamination of aviation fuel based on its unadulterated performance specification and in-flight needs.

This is a frankly unacceptable bottom-up approach from a self-interested part of the supply chain. What's needed is a top-down safety case starting from the approved JetA1 kerosene specification as recognised by air transport safety regulators and other parties. This should ensure that any FAME contamination doesn't degrade

Photo: Alexy Stiop – Fotolia.com

The U.S. Federal Aviation Administration sees a real future for biofuels, in particular the reduced sulphur content of such fuels potentially enabling, over time, lower, if not virtually non-existent levels of particulate matter.

the immediate, medium and long term performance requirements of jet engines and their fuel systems, or their safe day-to-day operation, based as they currently are on a tightly-specified petroleum-derived kerosene product.

It is vital that confidence is maintained in the integrity of JetA1 fuel and this episode shows, in our view, the unforeseen impacts that biofuel contamination from an unexpected source can have.

Where we are with alternative aviation fuels

Moving on to alternative aviation fuels themselves, there are some serious issues starting to surface with the safe in-flight performance of aviation-specific FAME biofuels.

The first flight earlier in 2008 from Virgin Atlantic can perhaps be dismissed as a PR stunt – it transpires

Strangely, it will be those countries that currently suffer from desertification that will be in the front line of next generation fuel supply. As oil runs out for the likes of the Middle East, so helophytes will be grown to replace lost revenue. In the eventuality that oil prices fall as biofuel production matures, the Middle East will be able to offset the two against each other. It is this sound economic reasoning that has seen the large Middle Eastern sovereign wealth funds move substantial funds for investment into the founding of sustainable helophyte fuel production development. The plants are able to grow in the desert sand with irrigation supplied by salt water... a perfect option for the Middle East and North Africa. With sound economics behind biofuel production through helophytes and the continued prosperity of the Middle East at stake it is hard to see fuel production through helophytes failing.

This development of helophyte sourced fuel coupled with the natural reluctance to rely on other countries for fuel could in turn lead to a surge in funding from western governments for the development of other sourced biofuels, such as algae. There are of course other options but it is algae and helophytes which offer the very best yield with the least environmental damage.

You could argue that the real joke is on those that have been hoping for a world that does not depend on the fractious Middle East region for fuel! When/if oil runs out you will be able to look over fields of helophytes in the sand and the real future beyond petroleum, in the very same region! Surely though it is nothing short of fantastical that humans could use the baron lifelessness of the desert to fuel future progress through organic growth, at the same time giving many of the poorest countries in the world a foothold on the ladder of prosperity.

Oil may well have fallen below the biofuel price range for now, but fuel derived from helophytes will become reality. With the Middle East now vesting so much interest in biofuel development some say that it is likely that we will see the birth of a biofuel cartel, much like Opec, by 2020. It seems increasingly likely that biofuel will be exchanged in the same manner as oil with the same spheres of influence: the more things change, the more they stay the same!

Philip Tozer-Pennington
Managing Director, AIP

Virgin Atlantic would argue that the 747 demonstration flight, using a biofuel composed of babassu oil and coconut oil (of which the oils are considered environmentally and socially sustainable), is helping to pioneer renewable fuel sources for aviation.

that the fuel used was never going to make it into production in any way, size, shape or form! Virgin's much-vaunted 747 flight from Heathrow to Amsterdam consumed 22 tonnes of fuel of which five per cent (1.1 tonnes) was biofuel. According to the fuel company Imperium Renewables's director of international business development, Brian Young, producing even that amount required the equivalent of 150,000 coconuts.

And as further reported in the May 2008 edition of *Petroleum Review,* "had the hour-long flight run entirely on biofuel, it would have consumed three million coconuts – an astronomical number that highlights the scale of the problem."

However, the flight did prove that with the right anti-freeze additive, which we believe was a (sustainable?) bioethanol product, the fuel seems to have stayed ice-free; that modern jet turbine engines are relatively fuel-tolerant under strictly controlled conditions; and that Sir Richard Branson will drink it!

There seems to us, however, to be a concerted, well-organised effort to run aviation biofuel trials in the full, sought-after glare of the world's media for what can best be described as the geopolitical aims of the global air transport industry to paint itself "green". The next flight test is expected to be Air New Zealand's 747 using a "second generation" biofuel, a 50 per cent blend of kerosene and a hydrogenated FAME from the nuts of the jatropha tree.

The fuel on this flight is, we believe, likely to be a hydrogenated vegetable oil. The hydrogenation process removes the oxygen to leave a diesel-type fuel not dissimilar to kerosene, with an acceptable fuel density and therefore a comparable range to kerosene.

Aviation consumes about 240 million tonnes of kerosene a year at the moment. With the very best jatropha yields – far from incidentally on already productive arable land that does compete with food production – about 1.7 tonnes per hectare, again *Petroleum Review* pointed out that "replacing that [current aviation fuel] would take almost 1.4 million square kilometers, well over twice the area of France". It added that: "In context, D1 Oils, the British company pioneering biofuel from jatropha in countries such as India, Zambia and Indonesia, plans to plant 10,000 square kilometers over the next four years."

Planting jatropha on marginal land that doesn't compete with arable land may be possible but will not achieve the yields quoted previously. And for many biofuels where marginal land may be considered for planting and harvesting, water resource pressures will be an important issue. But another significant potential problem with cultivating previously unused land for biofuels of any description is that by disturbing any such land, the stored carbon present may be released back into the atmos-phere and negatively impact the supposed "carbon balance" of the "plant-to-biofuel-to-end use" cycle in question.

At the Omega project's Alternative Aviation Fuel Conference held at the Royal Aero-nautical Society in London towards the end of November, 2008, we learnt that there are a range of available habitat/land use, water and fertiliser resource implications, "carbon balance" questions and competition between all other potential users of biofuels (such as road transport) that are as yet unanswered in the kind of detail that would allow any rational decision as to the likely future role of biofuels in powering commercial passenger aircraft. The economic viability of switching to any alternative aviation fuel, whether synthetic or an agro-fuel derivative is still an open book – with big questions requiring much more study and discussion.

Other hurdles to overcome are the exact effects the components in the chemical make-up of any new biofuel may have on topics as seemingly unrelated as jet engine performance and longevity, and human health impacts.

At the Omega event, Rolls-Royce and Sheffield University gave an update on the extensive test and analysis programme they are jointly running. It looks at what impact the metals likely to be present in conventional agriculturally-sourced bio-fuel, such as zinc and cadmium, could have on the performance and in-service life of aircraft engines and their components. Importantly, JetA1 kerosene's specification is for zero metal content; observations of differing combustion chamber flame luminosity between kerosene and biofuel with potential negative radiative heat impacts on internal surfaces; and investigating the potential for deposit build-up in parts such as fuel injector nozzles.

The U.S. Federal Aviation Administration (FAA) sees a real future for biofuels, in particular the reduced sulphur content of such fuels potentially enabling, over time, lower, if not virtually non-existent levels of particulate matter (PM), thus improving local air quality around large U.S. airports. In turn this allows compliance with tough, mandatory U.S. Environment Protection Agency PM Local Air Quality standards. This outcome will, it's fair to say, potentially happen only with a 100 per cent aviation biofuel, which we feel is some way off.

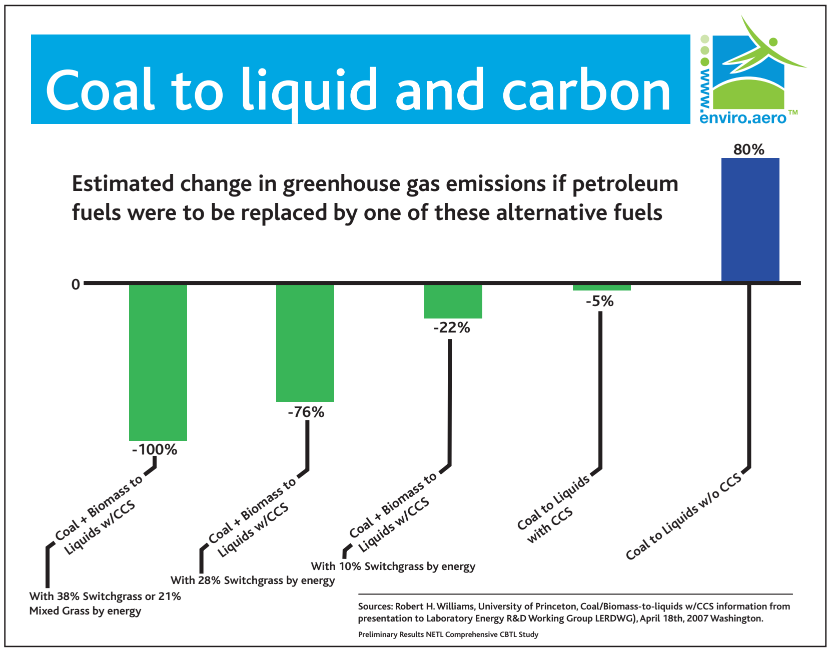
The FAA was also keen to establish its positive view of sustainable biofuels and perceived potential for "carbon neutrality", particularly in a maturing air transport market like the U.S. It also stressed the Department of Agriculture's interest in U.S.-sourced agricultural biofuels which could include subsidy interventions. The FAA supports and co-funds the U.S. Commercial Alternative Aviation Fuel Initiative, a good source of information about biofuel programmes as well as the huge efforts CAAFI and the U.S. military are putting into synthetic kerosene manufactured via the Fischer-Tropsch (FT) process, a programme being driven for well-documented energy security reasons.

The Department of Defense/U.S. Air Force programme has a Coal-to-Liquid (CTL) FT process, a so-called "drop-in" fuel as a direct replacement for kerosene at its core, plus several linked strands as the diagram on this page illustrates, all of which could be developed over time.

The CTL FT process, and its sister process Gas-to-Liquid FT, currently being developed and promoted by Airbus and Shell, produce nearly twice as much CO_2 as petroleum-derived kerosene. Not much environmental benefit there then!

The CCS element of the above chart is carbon capture and storage, without which the project's U.S. government strategic climate policy remit to end up with a replacement alternative synthetic or biofuel with at least the same, if not lower, carbon footprint than present-day kerosene (or the military jet fuel version) would not be met. CCS is a process where CO_2 is "captured" either by chemically removing or scrubbing production process gases, in this case CO_2, which are then sequestered in perpetuity by pumping into permanent underground storage in suitable sub-surface strata.

CCS would add extremely large costs, making the four "with CCS" elements potentially non-viable in our view at any stage of the chart. CCS is still a "drawing board" concept as far as we are concerned and we think it unwise to bank on such costly engineering "solutions" to sequester CO_2 as being at all likely to provide cost-effective solutions to greenhouse gas reduction strategies within a reasonable timeframe.



Political positioning?

There is currently a tremendous volume of noise concerning both synthetic and biofuels for commercial air transport. Much of this we feel is political positioning by industry and friendly governments to manufacture consent to keep expanding aviation in the face of growing demands for environmental limits, particularly in respect of the worrying increase in aviation's greenhouse gas and wholly negative climate change impacts. These Boeing comments are just one example of this gung-ho approach: "Certification will happen much sooner than anybody thought. We are thinking that within three to five years we are going to see approval for commercial use of biofuels – and possibly sooner." (*See news section for full story*)

We are not convinced that aviation would be the best end-user even if biofuels could be produced sustainably. We have also followed the increasing interest in algae as a potential source of aviation fuel but are unconvinced that any cost-effective algae-derived aviation fuel could be produced within a practical timeframe that would allow any such fuels to make any substantial contribution to climate change policies.

For us, the jury is still well and truly out as to whether either synthetic or biofuels are yet capable of being either entirely fail-safe for aviation use or environmentally sustainable in the longer term. All the avenues being explored today urgently need to be placed within a proper context – how does the world manage to include estimated aviation emissions growth within a low-carbon economy and developed world CO_2 cuts of 60-80 per cent by the year 2050? Answers on a postcard please!