Biofuels for Aviation:

More Future Land Grabbing and Deforestation for Agrofuels to Justify Today's Airport Expansion?

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Summary:

Biofuels and 'efficiency gains' are the aviation industry's two "green" promises, used to justify never-ending aviation expansion in the face of growing public awareness and concern over climate change. Biofuels play an integral role in the aviation industry's lobbying strategy, even though biofuels are not yet permitted for use in aviation fuel.

However, aviation biofuels are not just a lobbying gimmick. Oil and biotech companies, airlines and aircraft manufacturers, government agencies (particularly in the US) and venture capitalists are investing large sums into research and development of biofuels for aircraft. Recent test flights have shown that biofuel use in aviation is technically possible.

Right now, the refining process is highly energy intensive and technical hurdles will need to be overcome before aviation biofuels can be a commercially viable energy source. There are strong vested interests behind those developments – including the military and in particular the US Air Force, which is committed to sourcing half its fuel in the lower 48 US states from domestic non-oil sources (coal, natural gas and biomass) by 2011, due to concerns over 'energy security'.

A recent headline on an aviation industry website, "USAF drives biofuel bandwagon"[1] reflects the importance of military interests in this field.

A significant proportion of the research and development investment involves genetic engineering, particularly of microbes and algae – both genetic modification and synthetic biology, i.e. the attempt to create new, life-forms 'from scratch'. The risks to ecosystems, should such organisms escape, have never been assessed but could be very serious.

One of the research aims is to genetically engineer microbes which can 'liquefy' wood and other solid biomass in a matter of days or even hours. If successful, new demands for wood would greatly increase pressures on the world's forests and thus the rate of deforestation. Companies such as Virgin, Gevo, Amyris, Solazyme or Sapphire Energy might be looking specifically at genetic engineering for aviation biofuels, but it is difficult to predict what applications would be found for genetically engineered microbes or algae. Whether the applications will be in aviation biofuels or bioplastic, new markets will be opened up and there will be real and potentially very dangerous impacts on ecosystems and on society.

If biofuels for aviation become a realty, yet another biofuel market will be created, in addition to the already highly unsustainable and fast growing demand for biofuels for road transport, ensured through government targets and subsidies, and biofuels for heat and power (a considerably larger market for palm oil in Europe than biodiesel, at present, and one which also receives government subsidies).

Whichever biofuel technology or feedstocks are chosen, pressure on land and thus on natural ecosystems, food production and communities will grow further, exacerbating species extinction and the destruction of natural forests and other ecosystems which are essential for stabilising and regulating the climate. More pressure will be put on scarce and dwindling freshwater and on soils, and further reducing many people's access to food and to land.

Biofuels as a lobbying tool for aviation expansion

The International Air Transport Association (IATA) serves as a lobbying group for airlines, airport operators and other companies involved in aviation. In 2008, IATA successfully lobbied MEPs to water down requirements on the industry to reduce future emissions.[2] IATA have created the "Clearer Vision, Clearer Skies" website **www.enviro.aero/** .

As well as playing down the current climate and environmental impacts of aviation, this website promotes "sustainable biofuels" together with "efficiency" as "solutions". The website states: "One of the most exciting developments for aviation is the use of sustainable biofuels to replace the standard kerosene, or Jet-A, fuel that is currently being used."

This promotion is proving successful: The UK's Secretary of State for Transport, Geoff Hoon, recently addressed an aviation conference, saying: "One of the big challenges that many of you are embracing is to make commercial aviation biofuels a reality within five years and a major fuel source by 2050."[3]

In September 2008, several aviation companies set up the "Sustainable Aviation Fuel Users Group" to develop and promote biofuels in aviation.

In November 2008, various media reports suggested that Lord Turner, Chair of the UK's Climate Change Committee, had said that biofuels could allow UK climate targets to be met even if aviation expansion, including a Heathrow Third Runway, went ahead.[4] Lord Turner's speech had not actually included such a statement. However he did say that a global increase in aviation emissions was possible whilst cutting greenhouse gases overall and that this required a switch to "low carbon fuels" such as biofuels.

Which biofuels could be used in aircraft?

Since 2008, Virgin Atlantic, Continental Airlines, Air New Zealand and Japan Airlines have each carried out a successful test flight using biofuel blends. The highest blend was a 50% blend in one out of two engines, used by Air New Zealand. All of them used "hydro-treated renewable jet fuel" (HRJ), i.e. hydro-treated plant oil, made from different blends of oils from jatropha, algae, babassu nuts, coconuts and camelina.

Standard biodiesel and ethanol, the main biofuels used in road transport, are not suitable for most aircraft. Instead, there are three broad types of research:

1). ***"Hydro-treated renewable jet fuel" (HRJ fuel)***: Plant oils can be converted to aviation fuel, but need to be hydro-treated first. Hydro-treated jatropha oil, algae, coconut oil and camelina oil have all been successfully used during biofuel test flights. Hydro-treating other types of vegetable oil, including palm oil, is technically feasible.

Neste Oil are currently building the world's biggest palm oil biodiesel refinery in Singapore, state that their palm oil biodiesel would, after distillation, be suitable as a jet fuel.[6] They are the only company which produces biodiesel from hydro-treated plant oil at a commercial scale. This suggests that palm oil would be the most likely feedstock, should HRJ fuel be used on a commercial scale in the near future.

Palm oil is currently the highest-yielding biodiesel feedstock, and it is also the single biggest driver for deforestation in Malaysia and Indonesia,[7] as well as driving ecosystem destruction and displacement of communities and food production in many countries across Asia, Latin America and Africa. However, according to Neste Oil, even HRJ from palm oil is twice as expensive as regular jet fuel.

The only estimate for the amount of biofuels required for HRJ fuel is available from Virgin's biofuel test flight in 2008: Virgin used 5% biofuels in total during one flight from London to Amsterdam. **150,000 coconuts (as well as babassu nuts) were required to produce the biofuels for that one flight.**

2). ***Conversion of sugar-based biofuels to biofuels with similar properties as current aviation fuels:*** Aviation biofuels need to have similar properties to crude oil-based fuels, which is not the case for ethanol or standard biodiesel. Oil companies including BP and Shell, together with biotech and start-up companies, such as Gevo, Virent, Anellotech, UOP, Du Pont and Ensyn, are working on different processes to 'crack' biomass into different components which are then recombined to yield suitable fuel.

Different processes use either high temperatures (thermal conversion) or enzymes (biochemical conversion) or combinations of both to break down the biomass. Once sugars, such as cane sugar, can be converted, the aim is to use any type of solid biomass, including wood, corn stovers or wheat straw.

Some of the techniques being developed are:

+ Biobutanol and isubutanol:
BP, Dupont, British Sugar, Gevo (with funding from Virgin) and Oxford-based biotech firm Green Biologics are amongst those investing in biobutanol and isobutanol. BP, Dupont and British Sugar are building demonstration biobutanol refinery at Saltend, which is due to open in early 2010. Biobutanol and isobutanol involve fermentation by bacteria (usually clostridium acetobutylicum, but also E.coli). The fundamental problem is that the bacteria needed for fermentation do not survive butanol concentrations of more than 2%. However, butanol solutions of less than 8% cannot be efficiently separated from water, and very energy intensive distillation is required. Unless this problem is overcome, bio-butanol cannot produce any net energy. Overcoming this problem requires synthetic biology, i.e. engineering new microbes that can survive high butanol concentrations.

+ 'Biogasoline' from thermal conversion:
Shell and Virent, supported by Cargill and Honda, are leading investors in a process which they call "Bio-Forming". This involves a series of thermal or bio-chemical pre-treatments of the biomass, followed by a process called aqueous reforming which is also used in oil refining and which uses a catalyst to break down organic hydrocarbons into a series of components, including hydrogen, carbon dioxide and alcohols. The fuel is then separated from the water. Researchers are trying to simplify the procedure to reduce the amount of energy required. The pre-treatement of the biomass can involve either heat and acid, or enzymes, which would almost certainly require genetically engineered microbes. Shell and Virent operate a small pilot plant in the US and are planning to open a bigger one in 2009.

+ "Biocrude" from catalytic fast pyrolysis:
This is being researched by Shell, Chevron, Australia's national science laboratory, CSIRO, Ensyn, and UOP. UOP, a subsidiary of Honeywell, have refined the biofuels for all four test flights. "Biocrude oil" which can be further refined into aviation fuel, involves pyrolysis, i.e. exposing biomass to high temperatures in the absence of oxygen, in the presence of a catalyst.

3*).* ***Fischer-Tropsch gasification:***
This process involves exposing biomass or fossil fuels to high temperatures to turn it into synthetic gas (syngas), which is then turned into different types of liquid hydrocarbons, i.e. liquid fuel which can be used in cars or aircraft, called synthetic fuel. In South Africa, Sasol has long used this technology to make road transport fuel from coal. In 2008, Sasol had coal-to-liquids fuel certified for aviation. The same process can be used to make synthetic fuel from natural gas, coal plus biomass, or biomass on its own.

The problems with making synthetic fuel from biomass are the high capital cost, the high amount of energy needed for conversion, the cost of feedstock and the fact that large amounts of biomass are required to make the plants commercially viable.

The latter problem can be overcome if an intermediate step is used; pyrolysis. Such plants can be smaller and less capital intensive (though often very polluting) expose biomass to high temperatures in the absence of oxygen. This produces bio-oil and syngas, both of which can then be used as a far less bulky feedstock for Fischer-Tropsch gasification and can be further refined into aviation fuel. Pyrolysis also produces fine-grained charcoal as a byproduct which can be used as a fuel or in various industry processes, and which is currently being promoted heavily for 'biochar'.

'Biochar' is touted as a means of raising plant yields, reclaiming deserts and cooling the planet down to pre-industrial temperatures, with no credible evidence that it could do any of these.[5] If 'biochar' proponents have their way, this could earn substantial sums through carbon trading and as a fertiliser component in future and could help to make biomass gasification commercially viable – and with it, aviation fuels from biomass.

Biofuels from algae:

Biofuels from algae are promoted as the environmentally sustainable alternative to current agrofuels. Researchers are looking at using algae to produce different types of biofuels, including HRJ fuel and bio-crude for aircraft. The Continental Airlines biofuel test flight used a biofuel blend from algae and jatropha. However, the UK's Carbon Trust predicts that algal biofuels will not be commercially available until around 2020.[8]

There are inherent problems with this technology: Algae either maximise growth or they maximise oil production, not both. Growing just one 'optimum' type of algae would be difficult because those would be vulnerable to predators and to being out-competed by other algae. Closed 'bioreactors' provide higher yields than open ponds, but they require significantly greater capital and energy input. There are no commercial facilities and some investors now look at different markets for algae rather than biofuels.

Much of the research focuses on genetically engineering algae. The risks to marine or freshwater ecosystems if those algae were to escape have not been assessed and could be serious.[9] The company which supplied Continental Airlines with algae biofuels, Sapphire Energy, is one of five companies involved in genetic engineering research for algal biofuels, although the particular batch of algae used in the test flight appears not to have been genetically engineered.

In summary, aviation biofuels currently have such poor energy balances that they are not yet commercially available. However, at least for some types of biofuels, technical hurdles could well be overcome in the near future. The conversion of plant oil to jet fuel is so energy intensive and would require such large quantities of vegetable oil that the conversion of solid biomass, particularly through gasification, appears to be a more likely option.

If this technology was commercialised, pressures on the world's forests and other ecosystems would greatly increase and large-scale monocultures of fast-growing monoculture tree plantations would be required. Industrial tree plantations are a major driver of the destruction of natural forests and grasslands, commonly deplete groundwater and soils, support little or no biodiversity, are often prone to fire and storm damage and, particularly in the global South, are linked to the displacement of large numbers of communities, including indigenous peoples, and to the loss of food sovereignty.

The military interests behind aviation biofuels:

The US Air Force has the greatest ambitions for using 'alternative fuels': They aim to source half of their fuel for the lower 48 US states from domestic 'non oil sources' by 2016.[10] They also plan to ensure that, by 2011, all their planes can fly on a 50:50 blend of "synthetic" Fischer-Tropsch fuel and conventional fuel.

If they meet their target, then synthetic fuel from coal and natural gas can be expected to provide the bulk of 'alternative fuels', which would very significantly increase carbon dioxide emissions (particularly if coal-to-liquids fuel is used). The US Air Force programme is driven entirely by concerns about 'energy security', however, as a Federal Agency they are not allowed to procure synthetic fuel unless the life-cycle greenhouse gas emissions are equal to or less than for conventional fuel.[11] The life-cycle emissions from coal-to-liquids fuel, however, are at least 1.8 times greater. The two options for meeting this legal requirement are Carbon Capture and Storage (CCS) and co-firing with biomass. CCS is not generally expected to be commercially available before 2020 at the earliest.

Large-scale biomass use directly or indirectly causes land-use change. If natural ecosystems have to be converted, major carbon losses result and makes it less and less possible for remaining ecosystems and biodiversity to regulate the climate. Alternatively if food production and other agricultural activities are displaced, the agricultural frontier is pushed further into natural ecosystems, indirectly resulting in the same extremely negative result for the climate.[12] However, by ignoring all indirect land use change, by underestimating other emissions from industrial plantations and using different types of creative accounting, significant "greenhouse gas savings" can be produced on paper.

A joint report by the National Energy Technology Laboratory, the Department of Energy and the Department of Defense[11] suggests that around 5 million hectares of land for switchgrass and poplar or 3.18 million hectares of corn stover for biomass co-firing with coal to make synthetic fuel would be required to make the US Air Force 2016 goal compatible with US legislation. At present, there is uncertainty about the Air Force plans, following staff changes and a decision to drop a proposal for a large coal-to-liquids plant to supply military jet fuel.

Regardless of the outcome of this programme, it is clear that military interests play a major role in the development of aviation biofuels. The most important "stakeholder forum" for the development of aviation biofuels is the Commercial Aviation Alternative Fuels Initiative (CAAFI). The UK Ministry of Defence, the US Department of Defense, Defense Energy Support Center, US Air Force, the Defense Advanced Research Project Agency (DARPA) and the US Navy are all members of CAAFI. The US Federal Aviation Agency, in a presentation about CAAFI, has highlighted "Interagency Linkages with Defense and Agriculture"[13] in a presentation about aviation biofuel developments. In January 2009, DARPA awarded $25 million to the Science Applications International Corp to develop biofuels from agricultural feedstock and from algae for the US Air Force. Boeing, who were involved in all four biofuel test flights are also looking at 'military customers' with regards to biofuel development.[13]

UK actors in aviation biofuels:

Virgin Atlantic were the first UK airline to have set their own biofuel target: 5% by 2015. Virgin's Richard Branson first announced large-scale biofuel investment in 2006, when he pledged to invest $3 billion in "renewable energy", primarily biofuels. Virgin Group have invested both in US corn ethanol and in biotech companies researching and developing second generation biofuels, i.e. liquid biofuels from solid biomass. Richard Branson is on the Steering Group of the Energy Future Coalition, which has lobbied the US government for large-scale biofuel expansion, including for more biofuel investment by the Department of Defence. Virgin Atlantic is the only British member of the Sustainable Fuel Users Group, set up to promote and help develop aviation biofuels.

The corporate members of the Commercial Aviation Alternative Fuels Initiative (CAAFI) are not publicly listed – they include biofuel companies, airlines and aircraft manufacturers. Rolls-Royce, Shell and Airbus are known to be CAAFI members.

In the UK, Omega has been set up as a stakeholder forum to "explore solutions [to environmental problems] that are practical and deliverable" in aviation. One of the remits is research into possible aviation biofuels.

Whilst there are some members (or 'collaborative partners') of Omega who do not support aviation biofuels, UK Secretary of State for Transport, Geoff Hoon, has stated: "The work of Omega, and, in particular, Professor Chris Wilson at the University of Sheffield, has persuaded a – rightly – safety-focused industry to apply its minds to solving the technical problems and gaining confidence in using biofuels." Chris Wilson is the lead scientist in a study on aviation biofuels in partnership between Omega and Sheffield University. Biobutanol and isobutanol research, which is carried out in the UK by BP, Dupont, British Sugar, and Green Biologics is relevant for the development of so-called 'bio-gasoline' for aircraft.

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