Aviation and climate change:

Can alternative fuel save the day?

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Right across the global economy, carbon dioxide emissions from all sources are under attack in the fight against climate change. Energy efficiency programmes in all types of commercial enterprise, domestic oil, gas and electricity consumption in our everyday lives, investment in renewable sources of power generation, Government-sponsored information campaigns to encourage behavioural change, sustainable mobility policies, cap and trade emissions trading schemes, Kyoto targets and beyond, are all part of the policy armoury being deployed to drive greenhouse gas emissions down by 60-80% by the middle years of the 21st Century, if we are to avoid the worst impacts of climate change.

Commercial air transport is already a significant source of greenhouse gas emissions, responsible for around 700 million tonnes of jet-fuel derived CO_2 today, about 2.31% of total anthropogenic carbon dioxide. To put this into perspective, the entire UK economy, the 4th largest in the world, emits just under 600 MtCO_2. And future forecasts of aviation growth show CO_2 emissions from the sector rising rapidly and inexorably to more than 1 billion tonnes by 2025. Set against a background of emissions reductions from many other areas of the economy, air transport's overall share of greenhouse gas emissions will therefore increase too.

It needs to be pointed out that aviation emissions have an impact on climate change beyond just that of the sector's CO_2 emissions. NOx emissions, condensation trails and cirrus cloud formation all increase the degree of aviation's overall impact by a factor of between 2 to 4 times that of CO_2 alone, according to the current UN IPCC scientific consensus.

New technology is no match for rapid emissions growth

We know that there are 2 key areas that can make the aviation industry more fuel efficient over time: technological innovation and operational improvements. Technology can give us better engines, more efficient air frames, and increases in passenger volumes for each new class of aircraft designed and introduced into airline fleets. And better air traffic management and improved operational fuel-saving measures will also deliver worthwhile savings. Reorganising global airspace is frequently quoted as offering a 12-15% one-off efficiency gain – but even if all aircraft flew 'to perfection', this hugely costly improvement is wiped out by 2 or 3 years' growth. Of course ATM gains could and should be made but invoking their necessity on climate grounds is a bit of a red herring, as the sought after efficiency is driven in reality by cost per trip reductions and capacity growth rather than out-and-out climate change considerations.

The aviation industry points out, correctly, that large-scale efficiency improvements have been made over the years, and suggests that even greater improvements may be achieved in future. A more sober assessment by the UN IPCC (United Nations Inter-Governmental Panel on Climate Change) in its 1999 Special Report *Aviation and the Global Atmosphere* stated that:

> Historically, improvements in fuel efficiency have averaged at 1-2% per annum (measured as fuel burn per seat km) for new production aircraft. This has been achieved through new engine and airframe technology. A similar trend is assumed when projecting forward to 2050.

There seems to be general agreement with an estimate for overall fuel efficiency gains of between 1% and 2% p.a. as potentially achievable over the next 30 years or so, with a figure closer to 1%, under a scenario based on Airbus A380 and Boeing 787 type technology permeating through the global aircraft fleet, being, we believe, most likely. The higher 2% figure will be achievable only if there are tough regulatory and economic measures, or the price of oil rises and stays beyond US$ 125-130 per barrel, or a combination of all or any of these circumstances.

Late last year, the UK's Department for Transport neatly summed up where improvements have taken us so far and predicted a likely scenario for future improvements in this table:

Table 3.4: Annual average fuel efficiency to 2030

Year	Annual average improvement in fuel efficiency		
	DfT forecasts 2007	IPCC 1999	Historic average
2005-2010	0.8%	1.30%	
2010-2020	1.6%	1.00%	
2020-2030	0.6%	0.50%	1-2%
2005-2010	0.8%	1.30%	
2005-2030	1.0%	0.90%	
Aggregate 2005-2030	29.7%	33.00%	

Source: UK Air Passenger Demand and CO_2 Forecasts, DfT, London, November 2007

We broadly agree with this picture, questioning only the projected 2010-2020 period increase as on the high side. But overall emissions growth is forecast to be at least 3-4% p.a. over the same period leading to a significant performance gap as growth will simply outpace fuel efficiency improvements.

The UK Parliament's authoritative Environment Audit Committee put it succinctly in a March 2007 report when analysing a range of forecasts showing the all-too apparent contradiction between unrestrained aviation growth and the UK's greenhouse gas reduction targets, saying that they:

> …illustrate the difficulty - and, depending on certain growth projections - impossibility of meeting tough carbon reduction targets for 2050 and accommodating the ongoing expansion in flights.

Against this background of increasing pressure on the industry to do more to control and reduce its carbon emissions, alternative fuels have moved firmly on to and up the agenda as one way in which some or all of aviation's greenhouse gas emissions might be further controlled and reduced.

The search for a new aviation fuel: understanding the challenge

It's important to understand that alternative fuels have their own nomenclature, development specifications and pros and cons. All alternative fuels must be technically compatible with current distribution networks and aircraft fuel systems; they must offer similar fuel density, energy efficiency and overall performance characteristics to current petroleum-derived aviation fuel; they must be safe at altitude with acceptable freezing point performance and must not corrode or degrade on-board fuel systems or aero engine components; and they should, from the industry's viewpoint, cost the same, or less, than current jet fuel; production quantities need to be ramped up quickly in order to make a clear and measurable reduction in the sector's greenhouse gas emissions, the main question in climate change terms being whether such fuels have an overall benign or negative carbon balance

Synthetic alternative fuels fall into 2 categories. The first is coal-to-liquid kerosene type products and natural gas-to-liquid products using the Fischer-Tropsch process (German inventors of synthetic fuel process developed during World War 2). Biofuels are the other route, using bio mass material from sustainable sources as their feed stock that in an ideal world cause no additional competitive pressures on food production or agricultural resources such as land for food and water supplies, and that can produce an alternative fuel for aviation use, in a similar fashion to automotive biodiesel. Commercial aviation faces competition from military needs for politically and economically secure sources of alternative fuel, although they may be some useful advances in developments in one field being directly transferable to the other.

Current US research and development for military alternatives has a strong focus on both synthetic and bio fuel routes and the potential for carbon sequestration

So what is the current picture on the range of and progress towards commercial reality for alternative aviation fuels of all types?

US air force requirements developed by Darpa (Defense Advanced Research Projects Agency) programmes are currently out of the laboratory and into real life testing with CTL FT synthetic jet fuel (Military specification Jet Propellant 8 alternative) having been tested on B52 and BI bombers and this summer on the C17 military cargo aircraft.

Civilian FT process jet fuel (kerosene Jet A alternative fuel) from coal has for some years been produced in South Africa by the state oil company, Sasol. Aircraft using Johannesburg airport can fill up on a 50/50 blend of normal kerosene and synthetic FT fuel, although we understand this has just been certified for use in a 100% synthetic formula. The Sasol FT plant is a legacy of the now dismantled apartheid regime facing international trade sanctions during the 1970's and 80's, including restrictions on oil supplies, which forced the state to turn to the FT coal-to-liquid process for synthetic petroleum production, South Africa having plentiful coal reserves.

The synthetic CTL FT process can and does produce technically viable, safe aviation fuel in both civil, Jet A/Jet A1, and military, JP 8, forms. But there are 2 large questions looming over the potential switch for the US military – where, how and at what cost can presumably US-based CTL FT JP8 production be ramped up?

The problem with FT fuels: high cost and high carbon

The whole question of security of supply naturally dictates homeland located production facilities. US military requirements alone will be in the region of the 4.5 billion (US) gallons of JP-8 fuel used by the U.S. Air Force, U.S. Army and NATO annually right now. This is a huge amount and even the declared goal of the US air force to use a 50/50 blend of synthetic and petroleum based fuel across its fleet by 2011 is both costly and ambitious. The US air force search for alternative military aviation fuel is governed by regulations that state that the carbon footprint of any new fuel must not have a carbon footprint worse than the standard petroleum derived fuels in use today.

But there is a significant environmental problem with CTL FT fuel – the production process is hugely carbon intensive. Speaking in December 2007, the US air force assistant secretary overseeing the switch, James Anderson, said jet fuel from coal produced 1.8 times more carbon dioxide between production and consumption as jet fuel from oil, but added most of that additional amount could be captured during production of the synthetic fuel.

This last statement refers to the process of carbon capture and storage for which, as far as we can tell, there are only small scale test or development programmes currently underway, although there is certainly a lot of chatter! CCS removes CO_2 during industrial refining or other processes, such as coal-fired power generation, or as in this case, the FT process, by a chemical reaction or scrubbing; the gas is then collected or dissolved in solution and pumped away to containment areas in, for instance, suitable geological rock strata nearby, or put to other industrial uses, for example as a feedstuff for co-located algae biomass feedstock production plants. This last example is currently being promoted as an environmental win-win as the captured CO_2 feeds the algae, which in turn yields a supposedly carbon neutral bio fuel as the refined end product.

The only commercial scale application of CCS today is limited to parts of the oil industry where CO_2 is chemically separated/recovered from natural gas production flows, and then pumped under pressure into underground reservoirs to force out difficult to access oil or gas deposits. The economics of CCS are somewhat opaque at present, with planned trial schemes on one minute and off the next, as they are hugely dependent on –'will they, won't they' Government grants or tax breaks by way of financial support. We also think CCS schemes will turn out to be very costly in and of themselves.

Because of this, our view is that would be unwise to commit to large scale investment in CTL synthetic aviation fuels (or as we cover briefly below, its sister process GTL, gas –to-liquid fuels) without an absolute guarantee of effective simultaneous CCS systems being in place that sequester all production process related CO_2 emissions.

The industrial players

Earlier this year, Airbus entered the alternative race to gain column inches and green credentials by organizing a high profile test flight of the A380 aircraft from Bristol to Toulouse. This aircraft was powered by a Gas-to-Liquid FT process synthetic kerosene fuel. The test is linked to a consortium of Qatar Airways, Qatar Petroleum, Qatar Fuels, Qatar Science & Technology Park, Rolls Royce and Shell International Petroleum Company was set up in late 2007 to research the potential benefits of synthetic jet fuel processed from gas, as Qatar has huge reserves of natural gas.

This product is slightly cleaner than conventional fuel and CTL synthetic derivatives as it has almost no sulphur content and is also slightly more energy efficient than kerosene, as Airbus pointed out in a press release announcing the test flight from February 2008:

> GTL has attractive characteristics for local air quality, as well as some benefits in terms of aircraft fuel burn relative to existing jet fuel. For instance, it is virtually free of sulphur. Synthetic fuel can be made from a range of hydrocarbon source material including natural gas or organic plant matter made by a process called Fischer-Tropsch.

But labelling a fuel "green" is inappropriate in this case because as with CTL, GTL aviation fuel uses the FT process so it too has a larger carbon footprint than kerosene. Natural gas based CTL aviation fuels have no climate change environmental benefits without CCS being deployed as we have outlined previously.

The conversion of fossil fuel feedstock, whether coal or gas, to synthetic aviation fuel is therefore currently environmentally unsustainable and we have severe reservations regarding the cost and timely development of CCS as a process and successful technology to deal with the excessive production CO_2 emissions inherent in using the FT system.

Biofuels: more dream than reality

Biofuel is the other alternative aviation fuel route under development. Biofuel from sustainable feed stocks are under consideration in various percentage mixes with either conventional or synthetic aviation fuel or as a 100% formula. The latter looks highly unlikely as most biofuels under consideration lack the energy density of kerosene so are significantly less efficient – their miles per gallon performance is much, much poor with consequent range penalties for aircraft missions.

Commercial airlines including Virgin Atlantic, Continental Airlines and Air New Zealand all have headline-grabbing trials in place:

- Virgin Atlantic flew a Boeing 747 in February 2008 with one engine powered by a 80/20 mix of kerosene, an unsustainable so-called first generation biofuel made from palm oil and extract of babassu nut, plus a bio ethanol antifreeze component. The fuel and antifreeze components were supplied by a small Seattle USA based company, Imperium Renewables.

- Air New Zealand has said they will fly a 747 in late 2008 or early 2009 with one engine powered by a kerosene/biofuel mix. It is believed that this particular biofuel could be an algae-derived product and Boeing and Rolls Royce have signed up to this validation exercise. The biofuel is currently unidentified but Boeing Australia President, Craig Saddler, said in September last year that:

  > The Air New Zealand bio-jet fuel demo flight will highlight the suitability of environmentally progressive fuel solutions (bio-jet fuels) that differ from traditional biofuel development. Bio-jet fuels will incorporate second-generation methodologies relative to sustainable feedstock source selection and fuel processing, which are uniquely suited for aerospace applications. These bio-jet fuels can potentially be blended with traditional kerosene fuel (Jet-A) to reduce dependency on petroleum-based fuels. Additionally, sustainable bio-jet feedstock sources avoid deforestation practices and potential competition with global food resources, while helping to lower aviation carbon dioxide outputs.

- Continental Airlines are due to test a biofuel/kerosene mix in 2009, partnered by GE and Boeing. In March 2008, Billy Glover, director of environmental strategy at Boeing said:

> We are seeing a lot of innovation around biofuels for aviation. We're not ready to select a specific fuel yet. It will be a second generation biofuel, algae is on the list, other things such as babbasu nuts, halophyte plants, jatropha plants, switchgrass...work is going on in all those areas, and progress is pretty rapid.

This is a snapshot of where biofuel development is presently up to. All commercial and military aviation projects are coordinated and reported on by the Commercial Aviation Alternative Fuels Initiative consortium, a USA based project. Their Executive Director, Richard Altman, clearly laid out the content and timing, problems and opportunities for alternative aviation fuel R&D and end-use horizons in these graphics from March 2007 in a presentation entitled "Alternative Fuels in Commercial Aviation - the Need, the Approach, Progress" which is a clear and useful overview of the entire arena. (http://www.faa.gov/news/conferences_events/aviation_forecast_2007/agenda_presentation/media/9-%20Rich%20Altman.pdf)

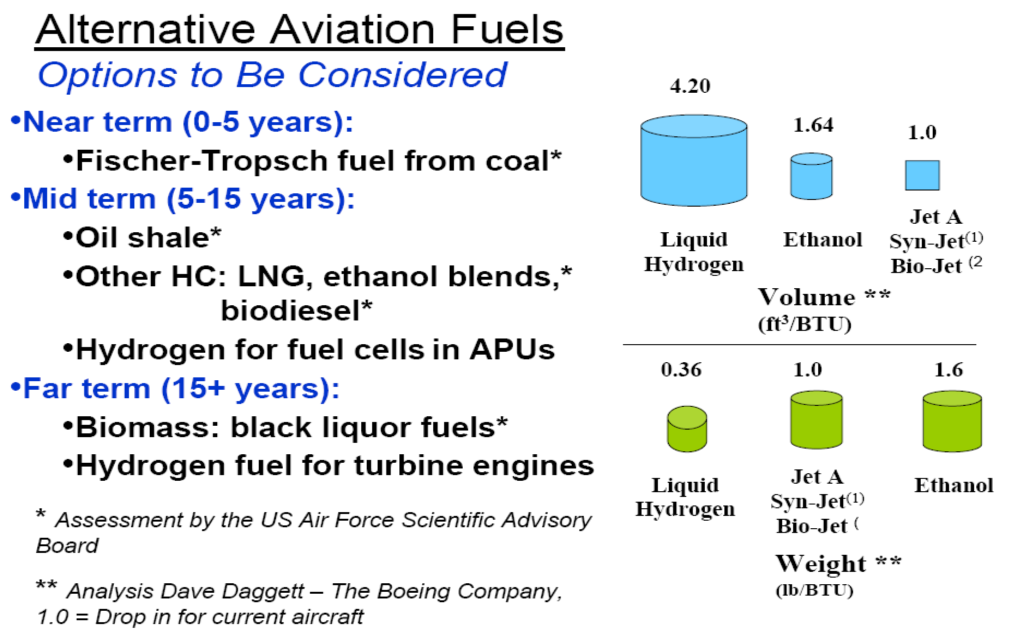
The future? Keep the options open, but don't expect any quick fixes

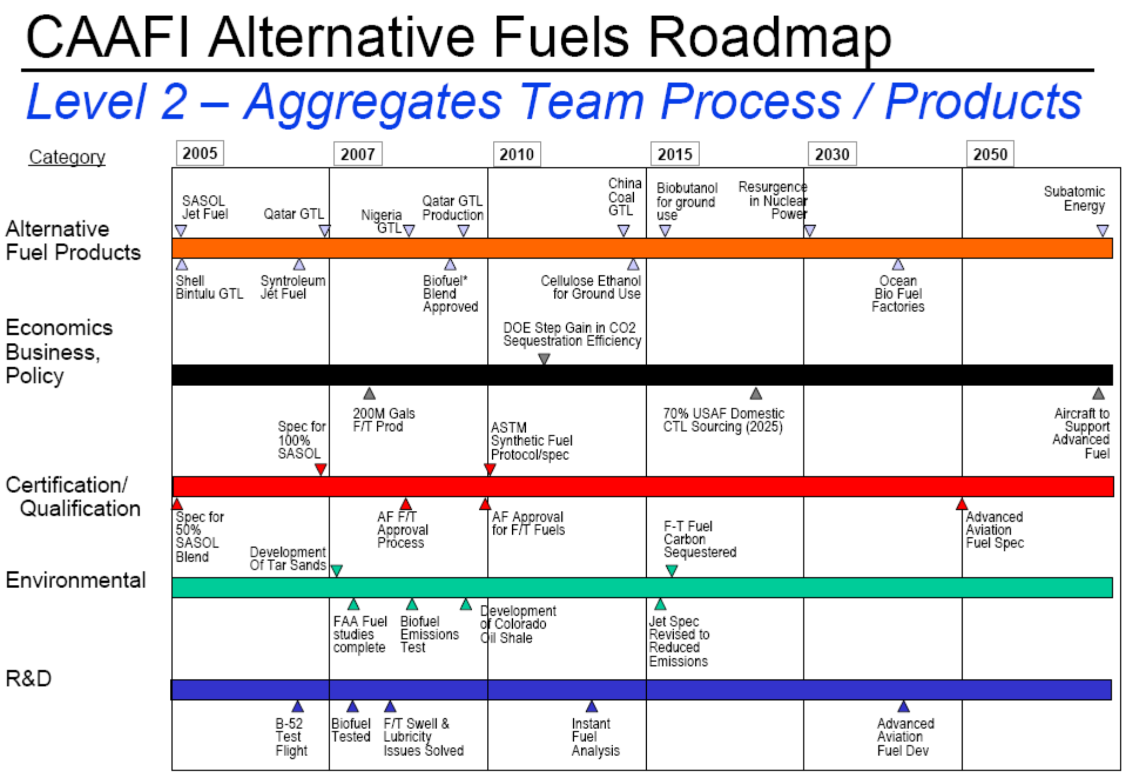
It is right and proper that all forms of aviation are looking at alternative fuels as CO_2 emissions from aviation need to be controlled, stabilized and ideally reduced by the middle years of this century. But we don't believe that any CTL/GTL derivatives should be manufactured without CCS being in place from day one – this doesn't seem to us to be on the table in either a reasonable time frame, given the climate change greenhouse gas reduction policy imperatives world wide, or at an acceptable financial cost. Meanwhile, biofuel from future sustainable sources seems to us to be still ever-so-slightly in the realms of science fiction with talk from some proponents of algae production facilities on top of sewage works, claimed yields of fantastic proportions, and flexible conversion/ production/distribution networks situated wherever demand occurs. We think a reality check is need is needed and the CAAFI information flow seems to be the best source.

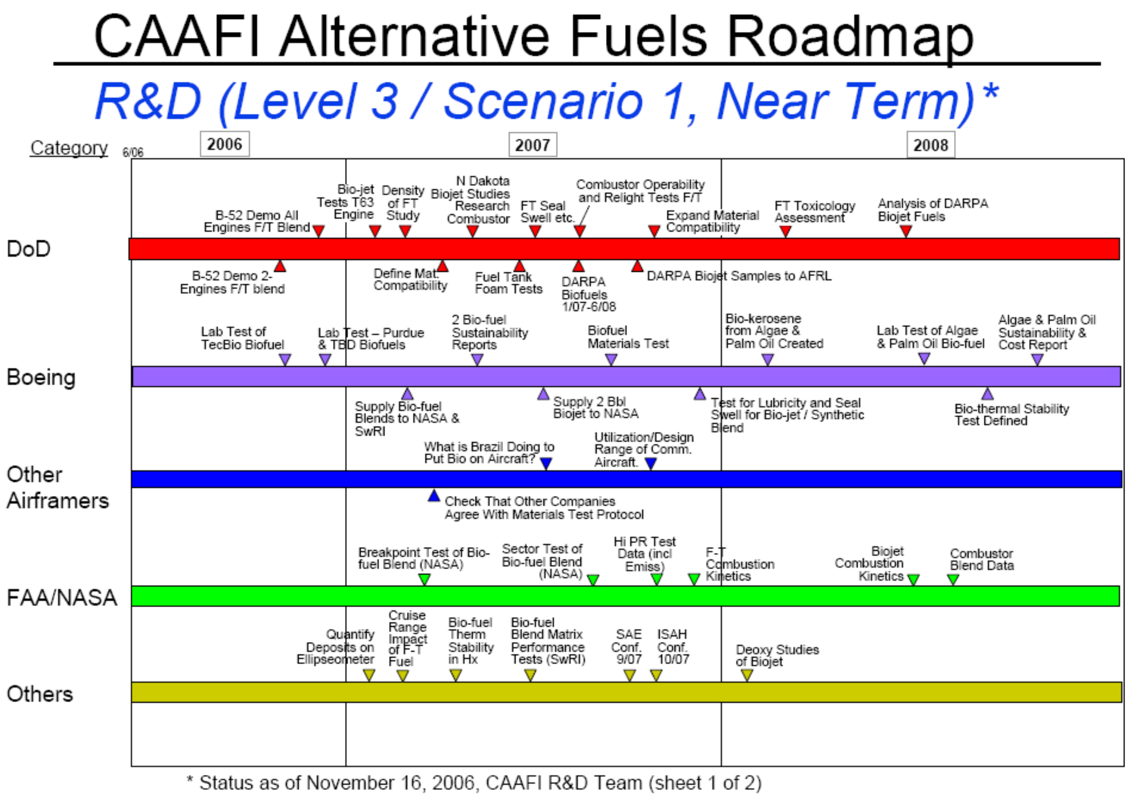
To end on a positive note, we have identified a single R&D project as our "one to watch". UOP, an Illinois based Honeywell group company involved in refining industry processes is currently researching biofuel technology for military jets. This type of research, which must be coupled with practical production means and CCS, is a way forward. But time is not on our side if we are to avoid the worst impacts of climate change. Our target for the commercial aviation industry would be 75% of aircraft fuel to come from completely sustainable biofuel production with refinery co-located CCS within 15 years. Any takers?

Annex

Commercial Aviation Alternative Fuels Initiative analysis, 2007







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