Biofuels: their emergence and implications for sustainability in aviation

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Abstract

The global aviation industry is facing complex and unpredictable market conditions with fluctuating oil prices and the adverse environmental impact of aircraft operations. Since the regulatory approval for biofuels, the first biojet fuel flight test in 2007, using a blend fuel, was a remarkable step towards having more test and schedule flights up to the year of 2014. The purpose of this paper is to engage this new alternative energy with the issues that airlines associate with sustainability, mainly focusing on aircraft operations and profitability. The key findings suggest that the uses of alternative energy need to be in parallel to the reliability and maintainability of the aircraft system, so that the adoption of biofuels can be effective.
Keywords: air transport, alternative energy, biofuels, aircraft maintenance, sustainability.

1 Introduction

According to IATA [1], airline passenger numbers are expected to rise by 31%, from 2.98 billion passengers carried in 2012 to 3.91 billion by 2017, with the Asia/Pacific region as the main contributor to this growth.

The growth of the industry is linked to an increase in the total emissions, which contribute to climate change. There has been several studies on climate change due to aviation since the late 60s and the early 70s (Kuhn [2]). The research was triggered by the potential stratospheric ozone (O_3) depletion, which was increased by the emissions from supersonic aircrafts (SMIC [3]). Later, the effects of nitrogen oxide were realized, which dramatically increased other research

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programs to identify the emissions and their effects from aviation. These include CO_2 emissions emission of particulate matter, the effects of contrails, and other aviation-induced cloudiness contrails (Steven and Merklein [4]).

The airline industry has recently started the adoption of alternative energy. Many terms have often been used to identify the classification of biofuels; "the first generation", "the second generation", and even "the third generation". This is further divided into two groups: *conventional biofuels* (first generation) and *advanced biofuels* (second and third generations), as shown in figure 1 (IATA [5]).

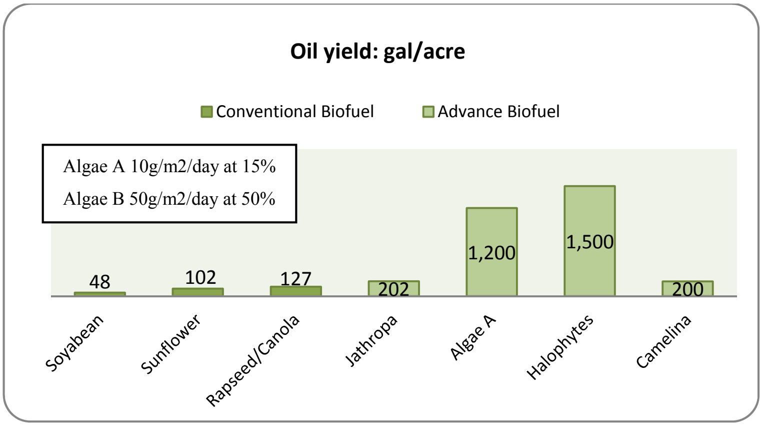

Figure 1: Conventional and advanced biofuel. Source: IATA 2009 [5].

Among these three biofuel generations, the distinguishing element is the technological advancement in terms of yield from biomass and the fuel efficiency. Many investigations and research have taken place and many more are still in the development phase. This is to ensure that this alternative biofuel can meet the supply and demand for future use. The advantages and the disadvantages lie in the biomass itself, which determines the projection for its readiness level for being in the global market (ICAO [6]). Developing a biojet fuel that is clean and cheap has become a concern of high priority within the aviation industry. The main problems encountered regarding land availability and sustainability mean that it is not prudent at this time to assume that in 2050 biofuels could account for more than 10% of global aviation fuel (Rosillo-calle *et al.* [7]). But recent research suggests that value from renewable energy technologies can be created and captured sustainably and innovatively by green business models (Nair and Paulose [8]).

Airlines need to adopt the new biofuels, but the most essential part is to ensure that it can be used effectively and affordably in aircraft operations and maintenance. In this case, it is crucial for the airlines to utilize the biofuels with affordable maintenance costs in order to ensure that the engine systems can continually and safely perform their functions with reliability. The Maintenance Review Board (MRB) will need to evaluate the changes in the maintenance program to check whether the tasks need to be eliminated or reinstated. In some cases, the maintenance program needs to be adjusted with the introduction of new elements to ensure its reliability and to conduct analysis in case of system failure or components failure (Sundaram *et al.* [9]).

In this paper, we try to look at how the biofuels have been adopted in aviation and what implications their use has for promoting sustainability in aviation. We also try to examine how the adoption of biofuels will affect aircraft operations and maintenance.

2 Biojet fuel evolution

Airlines fly across continents and need to refuel anywhere and so the goal is to establish local biofuel value chains on every continent. Such global supply chains require the infusion of huge amounts of capital, which can be achieved only through policy initiatives by airline alliances that combine aircraft manufacturers, allied industries, regulatory organizations, and various governments. The initiatives in this field include the Brazilian Alliance for Aviation Biofuels (ABRABA); the European consortium of airlines and bio-fuel conversion technology providers led by Airbus; an Australian consortium led by Qantas, the Sustainable Aviation Fuel Users Group (SAFUG), which features 21 airlines, three aircraft manufacturers, and a bio-fuel conversion technology provider; and the Sustainable Way for Alternative Fuel and Energy in Aviation (SWAFEA) of the European Commission. These alliances are characterized by a wide variety of involved stakeholders, including the airlines, the aircraft manufacturers, airports, biofuel companies, petroleum companies, NGOs, governmental agencies and funding agencies.

Figure 2 shows how the different stakeholders are playing a role in changing the global aviation biofuel industry. Table 1 gives more information on what carrier; type of biofuel; aircraft and destination details of the present airlines use of biofuels in the Asia-Pacific region.

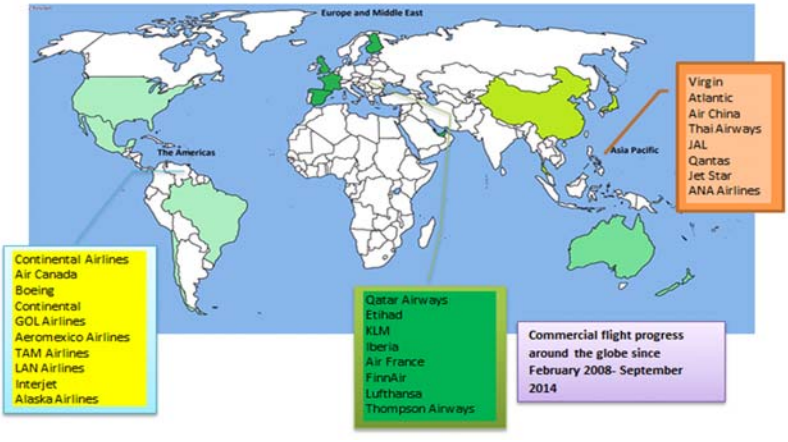

Figure 2: The commercial flight progress around the globe since 2008 up to September 2014.

Table 1: Asia-Pacific biofuel flight progress.

CARRIER	BIO-FUEL	BLEND	AIRCRAFT	DESTINATION
Virgin Atlantic	Coconut Babassu	20% one engine	B747-400	Amsterdam–London
Air New Zealand	Jatropha	50% one engine	B747-400	Two hour flight test
JAL	Camelina, Jatropha, Alage blend	50% one engine	B 747-300	Demo flight
Air China (CA)	Jatropha	50% of one engine	B747-400	Test Beijing airspace
Thai Airways TG	Castor seed	One engine	B777-200	Bangkok–Chiang Mai
Qantas	Cooking Oil	50%	A330	Sydney–Adelaide
ANA	Cooking Oil	10% blend	B737	Evertt's Paine Field (KPAE) to Haneda Airport (HND)
Jetstar	Cooking Oil	50% Blend	Dream-liner	Melbourne–Hobart

3 Biojet fuel adoption

The most important factor in the adoption of biofuels is going to be their cost with respect to using aviation kerosene. Fossil fuel use is increasing and their reserves are being depleted that will lead to fuel shortages in the near future. Airlines not only consider the fuel price, but also the implications the new fuel has on sustainability and cost gains in terms of operations and maintenance.

The alternative fuel being produced using (F–T) process was certified for aviation usage by ASTM International Standard D7566 in September 2009 (ASTM [10]). A 50% blend of (F–T) synthetic fuel with conventional fuels is currently used by few biojet fuel flight tests for use in commercial aviation. On July 1, 2011, ASTM approved the jet fuel product slate of Hydro processed Esters and Fatty Acids (HEFA) under alternative fuel specification ASTM D7566 (IATA [11]). HEFA fuel that meets this specification can be mixed with conventional jet fuel, up to a blend ratio of 50% (Liu *et al.* [12]). HEFA is currently the leading process for producing renewable jet fuel and several airlines that use this technology including Aeroméxico, Air China, Air France, Finnair, Iberia, KLM, Lufthansa and United (IATA [13, 14]).

In January 2009, the involvement of the Commercial Aviation Alternative Fuel Initiative (CAAFI), a research and development initiative involving various participants from Europe and the US, moved towards an established effort that the US Air Force and an Airbus proposal may possibly be brought together as a single Fuel Readiness Level (FRL), as shown in table 2 (CAAFI [15]).

Table 2: Fuel readiness level on the ICAO environment report 2010.

FRL	DESCRIPTION	TOLL GAT – progress updates
1, 2	Basic Principles Observed and Reported Technology Concept Formulated	Biofuel technologies including processes were identified
3, 4	Proof of Concept Process validation	No agricultural land required for growth of feedstock (e.g. biofuels from algae or biofuels grown with water from low-carbon desalination) may develop to change this picture and be fully optimistic
5, 7	Preliminary Technical Evaluation – Fuel Approval	ASTM D7566 approved
6	Full-Scale Technical Evaluation	Biofuel flight test/schedule flight conducted successfully since 2008 (Appendix 1)
8, 9	Commercialization Validated Production Capability Established	Internationally adaptation through methodology acceptance/ technically feasible and economically viable. E.g. full scale operational – SkyNRG-KLM

This development is very intense as the legislation for price and potential new carbon emissions affects the fossil fuels. At the same time, the growing global demand for air travel has led to collective motivated research to obtain more sustainable alternative fuels (ATAG [16]).

3.1 Biofuel adoption and aircraft maintenance issues

A turbine engine uses air as its working fluid, in the same way that blood does in our body. Every movement of the moving part needs a dynamic relationship regards all systems such as aircraft fuel and the metering system, lubrication and seals system, and the aircraft cooling system. Starting from the air intake, up until exhaust nozzles, complete combustion and actual combustion can be seen in figure 3 [17, 18].

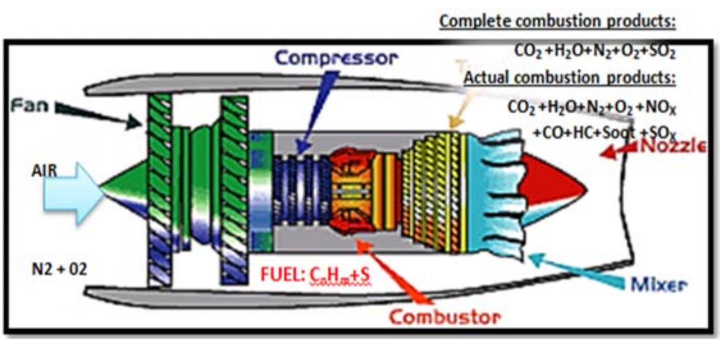

Figure 3: Turbine engine diagram with combustion products.

Maintenance comes after a great design. The ability to maintain and sustain the components, parts, and engine in the case of biojet fuel is vital. An aircraft turbine engine is very expensive compared to an automotive engine. Every single part such as bearings and seals needs to captivate, and further research on aromatics contents in the biojet fuel vs. normal kerosene fuel is still going on (Dufferwiel [19], Daggett *et al.* [20]). Examples of turbine engine components and its relationship towards biojet fuel maintenance is shown in table 3 (SAE [21], Lipa [22], Woodward [23]).

Table 3: Turbine engine components and their relationship towards biojet fuel maintenance.

Components	Functions	Relation to bio jet fuel maintenance
FUEL TANK	The fuel tank located in both wing and center of the fuselage. It holds the fuel for power demand form the engine.	Inspection of the tank needs to be evaluated for any seals property damage and micro biological growth corrosions that will lead to leak, cracking or pump blockage due to lack of Aromatics-substantial to add additives.
ENGINE FUEL PUMP/ ELECTRIC BOOSTER PUMP	The fuel pump is located on the accessory gearbox (AGB). The fuel pump pressurizes and circulates fuel within the fuel for fuel combustion.	The fuel flow needs to be tested for minimum requirement of flow rate (literally low for biojet fuel).
FUEL FILTER	The fuel filter is located within the lower section of the fuel pump and its corrugated construction is designed to retain foreign particles suspended in the fuel, and prevent blockage their entry into the MEC.	Normal sediment possibility comes from the tank or the biomass residue.
FUEL NOZZLES	Fuel nozzles are installed into the combustion case and are connected to a fuel manifold and drain manifold.	Results from the decreasing fuel flow rate led to a decrease in Fuel Nozzle supply, which enhances disturbance on complete combustion.
PMC	Power Management Control, which provides an electronic Adjustment of the MEC to obtain optimum power settings for take-off, climb, and cruise flight conditions without constant adjustment of the thrust lever by the flight crew.	Detailed data on new fuel enhance the change in the details. Specific gravity on the MEC position.
MEC	Designed to control fuel flow variable bypass valve (VBV) position, and variable stator vane (VSV) position on the engine. The MEC schedules the proper amount of fuel during acceleration and deceleration and regulates flow during steady-state operation to maintain a set core engine speed.	The specific requirements of fuel need to be met and adjusted accordingly.

3.2 Biofuel adoption and aircraft operations

Other than maintenance repair and overhaul (MRO), the airport infrastructure, air traffic management (ATM), airline operations, end-of-life recycling are among the main concerns in line with a broader scope for going green and sustainable in aviation. For aircraft operations, teams from the IATA (Green Teams) are advising all the members in terms of aircraft operation including fuel efficiency, covering ground operations, flight planning and operations, fleet renewal programs and aircraft upgrades with already certified improvements (Boeing [24]). In the year 2011, due to environment concerns, around 40 ground support vehicles in the Amsterdam Schipol Airport were 100% powered by biodiesel. The commitment in introducing more sustainable transport is necessary as electrical power is not currently suitable for all type of vehicles.

While non-related to biofuel adoption, Air Traffic Management (ATM) enhancement progress will enhance the reduction in aviation emissions where IATA currently is working close with Civil Air Navigation Services Organization (CANSO), Air Transport Action Group (ATAG), Radio Technical Commission for Aeronautics RTCA, EUROCAE, Airlines Electronic Engineering Committee (AEEC) and more (Ribeiro *et al.* [25]). Since the 1930s, changes in air navigation systems have been introduced in a very systematic way. The primary concern on top of all others will be the 'safety'. Any changes, modifications or amendments will be analyzed with extremely careful testing and consultation. Air traffic management does not work alone. From ATM, two types of reduction can be contributed; CO_2 reduction and fuel consumption reduction. By the implementation of projects in Single European Sky project by SESAR, the average fuel consumption per flight can be reduced by up to 10%. The implementation will be in between 2013 and 2030, where around 50 million tonnes of CO_2 can be avoided (IATA [26]).

4 Conclusion

Air transportation is adopting sustainability at different levels. Adopting biofuels has been a major factor in this with major airlines involved in multiple initiatives around the world. Airlines look at multiple factors such as costs, regulatory and operational aspects, while adopting new fuels. We have looked at these issues and have come to the conclusion that adopting biofuels has positive impacts on the maintenance and operations of aircrafts. The cost benefits are long-term and will have more positive impacts as petroleum fuels become scarce and the environmental costs of using them become a major factor in cost benefit analysis of airlines. Airlines should adopt biofuels in a major way as it leads towards their long-term economic and environmental sustainability.

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