COMMERCIAL AVIATION ALTERNATIVE FUEL AND A REVIEW ON ITS FUEL READINESS LEVEL

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ABSTRACT: *Commercial alternative fuel and renewable energy need to be instigating in the route of sustainability. Previous research has shown that sustainable energy address environmental issues such greenhouse effects, climate change, and global warming. As aviation is concern, fuel price is the biggest enemy to many Airlines and new technology is not creating zero carbon emissions. Utilizing this new alternative energy will creating new solutions to the problems. This paper will review all flight test and schedule flight using alternative fuel from the year 2008 until 2016 and the projections on this new fuel have been measured through its Fuel Readiness level. The outcomes from this research can be demonstrated from its readiness in the perspective of the usage of the types of biojet fuel, fuel safety and performance of the fuel. As a result, it is expected to reduce the dependence on the fossil fuel enhance creating a better environment.*

Keywords: Commercial Alternative Fuel, FRL (Fuel Readiness Level), Bio jet fuel flight

1. INTRODUCTION

According to Commercial Aviation Alternative Fuels Initiative [1] , Fuel Readiness Level (FRL) has being developed to facilitate the development and deployment of alternative jet fuels that offer equivalent levels of safety and performance[1]. It compare favorably on cost with petroleum-based jet fuel that offers environmental improvement and security of energy supply for aviation. CAAFI have developed a table that consists of Toll-Gate from level 1 to level 9, where each level shows the development and deployment of that alternative jet fuel to the aviation industry. FRL help to organize and track the research and development milestones from the process of theoretical, developing, certifying, and supplying alternative fuels to commercial aviation [2]. The relationship for FRL to environmental issue and aviation fuel price indicate that Alternative fuel linkage with sustainable and renewable is very crucial.

Environmental Issue Related to Aviation

Air Transport Action Group (ATAG) stated that in the year 2015 flights, it had produces 770 million tons of CO_2 worldwide. The demand for air transport is continually growing tremendously hence it also affected the environment terrifically such as Greenhouse Gas(GHG) effect, Global Warming, and Climate Change. Aviation industry has contributed about 12% of CO_2 emissions from all sources of transportation compared to 74% from road transport, from that the largest source of carbon dioxide emissions in the aviation industry is the fuel used by an aircraft[3].

Alternative Fuel

Alternative Jet Fuel or also known as AJF can be classified as any fuel that is not derived from petroleum where its properties are similar to standard kerosene. AJF can be derived from biological material, coal or gas. Coal and gas will be not discussed in this paper as its sustainability has been questioned [4]. The first type generation of biofuels is liquid biofuels which undergo the simplest conversion process that usually from the edible feedstock such as vegetable oils or simple sugars and starches [5]. Second generation biofuels or advanced biofuels are produced from inedible raw materials left over from crops, woody biomass and other plant material that contain cellulose. Due to the discussion on the matter of sustainability and as aviation is concern, all resources from edible crop need to be eliminated, and focus will be on the promising short and long term. In this case, third-generation biofuels are the most suitable crops to be used [6, 7, 8].

2. METHODOLOGY

Journals and environmental reports in the context of Fuel Readiness Level (FRL) were reviewed and details content analysis of the efficiency of FRL in Biojet Fuel development and deployment focusing in the Aviation industry. The FRL level 1 to FRL level 9 has Standard Operation Procedure (SOP) for each level where the details of the content are verified and emphasis. The method also included details analysis on flight test and schedule flight data using biojet fuel and other alternative fuel used.

3. FUEL READINESS LEVEL

According to FAA, as for April 2016, ASTM already certified five bio-based jet fuel that has been authorized for air travel. The most recent fuel is known as Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK). This renewable energy has been derived from an alcohol called isobutanol, produced from renewable feedstocks such as sugar, corn, or forest wastes will discuss in details FRL level [9].

CAAFI has developed the Fuel Readiness Level scale, where the sponsors and modified in consultation with a principal energy supplier, an OEM stakeholder, and a fuel process technology developer. It provides a gated process to govern communication of technology maturity leading to a qualification, production and, deployment readiness.

Table 1: Fuel Readiness Level Toll Gate [1]

FRL	DESCRIPTION	TOLL GATE-progress updates
1,2	Fundamental 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
8,9	Commercialization Validated Production Capability Established	International adaptation through methodology acceptance/technically feasible, and economically viable, e.g. full-scale operational- SkyNRG-KLM.

FRL 1 and FRL 2

The level 1 and 2 in FRL is the preliminary level where the concept and principles being formulated and the detail identification of the feedstock. The potential feedstock includes conventional sources of biomass such as algae, crop-oil, forestry waste by-products and solid biomass [6, 10, 11, 12]. As sustainability is a concern, the most optimistic feedstock can be classified as short term, and long term feedstock will be Algae, Jatropha, Halophytes, and Camelina. Until now, the feedstock will be processed using technology formulated process as below:[13]

1. Fisch-Tropsch synthesis of kerosene
2. Methanol synthesis
3. Ethanol synthesis
4. Hydrogenation of bio-oil
5. Biochemical conversion to ethanol

FRL 3 and FRL 4

This stage of FRL is the development and concept process validation. American Society for Testing and Materials (ASTM) was responsible for doing testing of the processing method under:

1. ASTM D4054 – "Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives."
2. ASTM D7566 – "Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons."

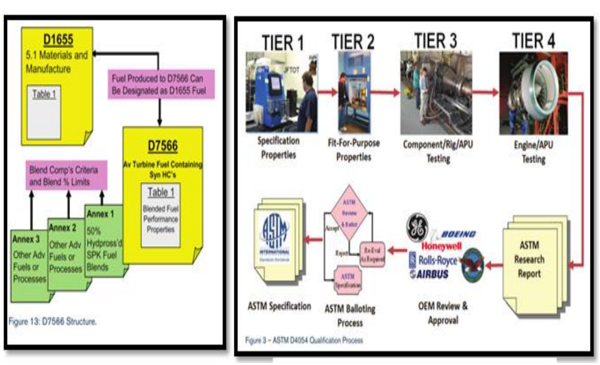

Figure 1: ASTM Extensive test program and performance

In getting the fuel qualification and approval, there will be a lot of extensive test program to test the performance and safety of the fuel pathway as shown in figure 1. The results are submitted to an internal review by the OEMs so that it can reach the stage of possible specification change, thus, only then it can be included in a new annex to ASTM D7566 [13].

FRL 5 and FRL 7

The FRL 5 is fuel process validation after it succeeds all the testing and meets all ASTM specification needed. While the FRL 7 is fuel approval and listed in International fuel standard level, once the new Alternative Jet Fuel (AJL) got approval and ready to be commercialized. As in April 2016, there is already five fuel pathway that has been approving by ASTM. Below is the list of the approval alternative fuel path:

1. FT-SPK and FT-SKA (with aromatics) which both of it use variety sources from renewable biomass. (Approve in September 2009)
2. HEFA-SPK fuels which use fats, oils, and greases. (Approve in June 2011)
3. SIP which converts sugars into jet fuel. (Approve in June 2014)
4. ATJ-SPK is created from alcohol called isobutanol which is derived from renewable feedstocks such as sugars, corn or forest wastes. (Approve in April 2016)

FRL 6: The Biofuel Flight test

From the year of 2008 where the first biojet fuel flight test until the year 2016, there is about 39 flight test and schedule made with the various types of alternative fuel. The flight test listed in the table below demonstrates completed details provided by the airlines. Lack of information such as the type of alternative fuel use, the exact date of the flight and also the types of aircraft used, it is impossible to include it in this research for analysis [14].

Figure 2: Aviation Biojet fuel roadmap

In March 2016, the United Airlines begins using biojet fuel in routine LAX flights. It is the first airlines in the United States to used biojet fuel in commercial scale. As in Europe, January 2016 shown that the Oslo Airport collaboration with Lufthansa Group to confirmed using biojet fuel from Air BP Aviation. Since the successful of BurnFAIR projects in 2011, Lufthansa decided to keep continuing in showing the support for research, trials, and use of Alternative fuel [15]. In other words, this proves that biojet fuel is no longer in the state of flight test, in fact, it is already used for regular commercial flight.

The figure below shows the types of aircraft used to conduct biofuel test flight. This data is a result of details flight based on figure 2.

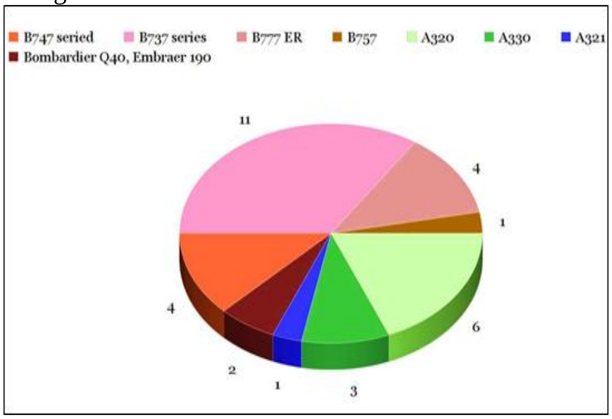

Figure 3: Types of aircraft used for biojet fuel flight

As a result, the type of aircraft that is widely used for flight test is from the B737 series which is 11 flights. Meanwhile, the second higher types of aircraft used in six flight tests are from A330 and the least type used from A321 and B757 with only one flight test.

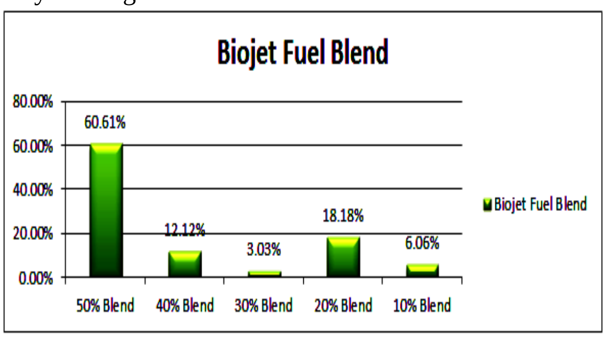

Figure 4: Biojet fuel blend from previous 2008 until 2016 biojet fuel flight

In figure 4, the highest fuel blend used for biojet fuel flight is 60.61% with a 50 % blend consist of fuel from jatropha, algae, camelina, GTL- Gas to liquid, cooking oil, Brassica, and carnita. Meanwhile, the second higher fuel blend is 18.18% with a 20 % blend which is using alternative fuel from coconut, babassu, jatropha, cooking oil and camelina. The least percentage of fuel blend used is 3.03% with a 30 % blend which is from alternative fuel type jatropha.

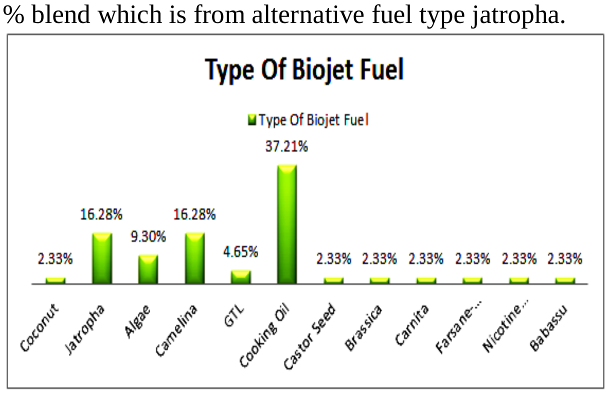

Figure 5: Types of Alternative fuel used for flight in the year 2008-2016

As in figure 5, the higher usage of biojet fuel for flight test is cooking oil which has been used for 37.21% or 16 times from total 39 flight test listed from the table 2. Meanwhile, the jatropha and camelina are the second highest biojet fuel used for flight test with 16.28% or 7 times usage from the year 2008 until 2016 as stated in Table 4. The least type used for biojet fuel flight is coconut, castor seed, Brassica, carnita, farsane-sugarcane, Nicotine Tobacco and babassu contribution of this is used for 2.33% or once flight test only.

FRL 8 and FRL 9

The alternative fuels commercialization validated with the production capability established. For example, the SkyNRG is one of the world market leaders for sustainable kerosene. From IATA Report of Alternative Fuels 2012, SkyNRG had supplies biojet to KLM/Air France for over 200 flights and provided fuel to multiple flights at the United Nations [16].

With the efforts by the SkyNRG do in developing the biojet fuel, the consumption by an airline has been improved from time to time. Thus, it will help the real purpose of reducing aviation's environmental impact globally. Perhaps in the future, all airlines in the world will be using 100% biojet fuel to the fly.

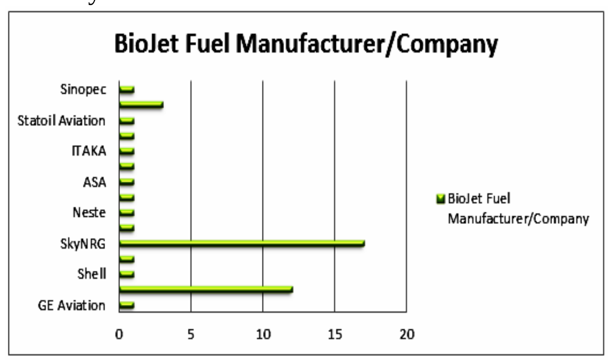

Figure 6: Biojet fuel manufacturer/company provider for flight test 2008-2016

The biojet fuel producer for the aircraft flight test, as can be seen in figure 6, SkyNRG has the highest number of flight test done of 17 flight test from entire 39 flights as shown in figure 2. Meanwhile, the second largest biojet fuel manufacturer is the Honeywell UOP which has done 12 flight test out of 39. For the least number of flight tests by the biggest fuel manufacturer with only one flight test out of 39 are GE Aviation, Shell, Rentech, Solazyme, Neste, Sustainable Oil, ASA, LAN, ITAKA, Amyris-Total, Statoil Aviation and Sinopec.

4. CONCLUSION

To implement Biojet Fuel in the aviation industry through Fuel Readiness Level procedures, Commercial Aviation Alternative Fuels Initiative (CAAFI) Environment team held many conferences and seminars with fuel manufacturer, Airlines and Engine manufacturer around the world such as Shell, GE Company, Airbus and Boeing. Nowadays, many AJF research has carried out and implement in the Aviation industry.

The sustainability of biojet fuel generation from the first generation to the fourth generation mainly will be focusing on the environmental benefit, its biodiversity, the ability in eliminating the food versus energy conflict as Table 2 below.

Table 2: Sustainability of biojet fuel generation

Sustainability of in biofuel generation	**1st generation**	**2nd/3rd generation**	**4th generation**
An environmental benefit	Provide Initial breakthrough	Close to meeting Environmental benefit	Ongoing
Biodiversity	Negative impact	Lower conversion rate	Not relative known
Food Vs Energy	Higher food price competition	Lack of technological and research breakthrough	Technological and research still ongoing
Social and environmental impact	Claimed to have both benefits	Benefits both	Initial thought, not proven

The social and environmental impact of this new alternative energy mainly focusing on biofuel will need to be investigated in further research as its direction to Sustainability. As fuel readiness is concern, in ensuring every level is meeting its full capacity, three things need to focus such; supply change stability, an off-take agreement and a stable platform for ready to scale technology.

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