Biofuel, An alternative source for Jet fuel in Aviation

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Dissertation in Energy Engineering, 15 credits

2017-09-06
ABSTRACT

The transport industry is one of the fastest growing industries with the sector playing a significant role in negative impact on global warming and pollution through the emission of greenhouse gases. Aviation in particular, has enjoyed growth especially in the few decades. New airlines and aircraft manufacturers are coming up with different innovations and technologies to ensure they make the best possible environmentally friendly aircraft. The new main area of focus has been on how to come up with fuel that will reduce the greenhouse gas-emissions. The stakeholders in the same effort include developed nations like the United States, United Kingdom, Russia, France, Germany, and Canada among others. Energy providers as well as jet fuel suppliers are also making efforts to conserve the environment. The purpose of this thesis is to explore the area of biofuel in aviation by looking into various stakeholders involved in the efforts of the transition from fossil fuel to biofuel. The conclusion of this thesis is that biofuels are viable options in the aviation industries since there have been positive results in the tests made.

Keywords: biofuel, biogas, pollution, aircraft, airline, aviation and environment
SAMMANFATTNING

Transportbranschen en av de snabbast växande branscherna och sektorn har en stor negativ påverkan på den globala uppvärmningen genom förorening och utsläpp av växthusgaser. Särskilt luftfarten har haft en kraftig tillväxt under de senaste årtiondena. Nya flygbolag och flygplanstillverkare har arbetat fram olika innovationer och teknologier för att säkerställa bästa möjliga miljövänliga flyg. Fokus har legat på att hitta det bränsle som ger en minskning av utsläppen. Likasinnade intressenter finns bland annat i utvecklade länder som USA, Storbritannien, Ryssland, Frankrike, Tyskland och Kanada.

Energileverantörerna såväl som jetbränsleleverantörer gör stora ansträngningar i strävan att värna om miljön. Syftet med denna studie har varit att utforska området biobränsle inom luftfarten, genom att granska arbetet hos olika intressenter engagerade i detta område. Slutsatsen i detta examensarbete är att biobränslen är lönsamma alternativ inom flygindustrin, eftersom tester har givit positiva resultat.

Nyckelord: biobränslen, biogas, förorening, flygplan, flygbolag, luftfart och miljö
ACKNOWLEDGMENTS

The work posed in this thesis is by far the most important attainment in my life and it would be unimaginable without people who affirmed and believed in me.

First and foremost I am grateful and thankful to my supervisor Dr. Heidi Norrström for her exemplary guidance, supervising and constant encouragement throughout the course of this thesis.

I would also like to thanks to all my tutor from my program who gave me support and suggestion about studies and my career.

Finally, My heartfelt gratitude towards my mother, Arjumand Amin and my father, Md. Aftab Alam who were constantly supporting me from abroad during my studies in Sweden.
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LIST OF ABBREVIATIONS

AJF – Alternative Jet Fuel
ASTM – Standards and Specifications for Biodiesels Blended with Middle Distillate Fuel
ATM – Air Traffic Management
CAAFI – Commercial Aviation Alternative Fuels Initiative
CISCO – Commonwealth Scientific and Industrial Research Organisation
CO2 – Carbon Dioxide
EC – European Community
EPA – Energy Protection Agency
EU – European Union
FAA – Federal Aviation Administration
GE – General Electric
GHG – Greenhouse Gases
IATA – International Air Transport Association
ICAO – International Civil Aviation Organization
IDB – Inter-American Development Bank
IEA – International Energy Agency
KLM – Dutch Airline service provider

LanzaTech – Steelmaker Company

MASBI – Midwest Aviation Sustainable Biofuels Initiative

MoU – Memorandum of Understanding

NOx – Nitrogen Oxides

NRDDI – National Renewable Diesel Demonstration Initiative

QIBEBT – Qingdao Institute of Bioenergy and Bioprocessing Technology

RFI – Request for Information

SBRC – Sustainable Bioenergy Research Consortium

SkyNRG – Global supplier of Jet Fuels

UK – United Kingdom

UN – United Nations

UOP – Universal Oil Products

US – United States

USDA – United States Department of Agriculture
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Aim and Objectives of the Research

The primary purpose of this research is to explore the subject of biofuel in the aviation industry. The airline industry is blamed for being among the biggest contributors to the GHG emissions and therefore among the largest contributors to the global warming effect. The goal of this (paper) thesis therefore, is to explore an alternative source of clean energy and efforts made so far in the adoption of clean energy in the aviation industry. This descriptive study will provide data on the current statistics on the contribution of conventional fuels to the emission of the GHG. It will also report on how biofuels, are expected to reduce the emissions by the year 2020 and 2050. The study will also focus on the various initiatives in place as well as the progress made by the various stakeholders including governments, organizations, aircraft manufacturers as well as airlines firms and energy providers. Lastly, I will outline some of the challenges that are facing the growth of the biofuel industry, and why airlines such as the Lufthansa are reluctant in the adoption of the alternative jet fuels.
Methodology

The focus of the research was on the viability of biofuel in the aviation industry. Various factors, both internal as well as external factors, were reviewed in completing the research. Some of the internal factors included how the aircraft manufacturers and operators have responded to the research while the external ones involved the availability of the feedstock as the environmental pollution regulations. The information used in developing the research was gathered from primary and secondary data collection methods. Research were made by visiting various air industries and government websites and also by going through the research paper and articles based on biofuel and aviation industries. The data collection methods involved relying on previous research made within the sector. The validation and reliability of the data collected depended on the supporting evidence to minimize the issue of personal opinions and bias.
1.0 Introduction

According to reports from experts, the aviation industry is a significant contributor of the greenhouse gases with an estimation of approximately 3% of all the emissions by various sectors in general [12]. Different stakeholders are focusing on various ways to reduce the gases and turning on the green energy sources as an alternative method. Other than the pollution, there is fear that at one point in time the petroleum that is the primary source of energy currently will be depleted since they are just extracted and not renewable [28]. Therefore, there are efforts to look for alternative and also conserve whatever is remaining. Commissions such the European Union and the United States as well as various airlines and energy companies have been busy to settle this since towards the end of the last decade they have made an effort to utilize biofuel as the alternative [20]. Different conferences around the globe, with the various stakeholders signing various agreements and memorandums of understanding as well as others are doing individual or joint investments on adopting the same concept.

Figure 1: Published Aviation Biofuel Targets (tonnes per annum)[20]
Unlike the currently used fuel which causes pollution, green energy is considered to be the cleanest energy, and it is renewable. Biofuel is produced from various sources such as corns, sorghum, and sugar among many others [25]. According to study from the experts in the field, technological improvements are expected to extensively play a major role, and the aviation industry is expected to make significant strides by the year 2050. Most of the results and tests presented are especially from the year 2005 to 2014 with companies competing in the field to ensure they are among the first to transform fully [14]. However, the utilization of the biofuel is expected to be partial as most of the current experiments contain 50/50 mix with other jet fuels [22]. Biofuels are gaining interest and public acceptance. This is due to their benefits especially since the prices of fossil fuels are unpredictable and governments are even offering subsidies to companies interested in the biofuel production.

1.1 Definition of Biofuel

Biofuel is an alternative source of energy that is continuously created from biological carbon fixation, and it incorporate fuels that are made from biomass conversion and liquid fuels like cooking oil and different type of gases. Even though fossil fuels contain carbon in them, they are not considered biofuels by the general definitions since it contains some carbons that are deemed to be out of the carbon cycle for a very long time. Some of the sources that are known for the production of the biofuel including sorghum, corn, sugar, vegetable oil and sugar among others. Some of the various countries known for their utilization include Brazil and the United States [25]. Europe has also not been left behind with countries like the United Kingdom, France, and Germany being on the forefront.

Currently, the bioenergy is believed to account for approximately 10% of the world energy, and it can be in solid form and liquid as well as gases [17]. However, the literature mostly recognizes only a small definition of biofuels to mean the liquid part of it since the world is concerned on replacing the fuel in the transport industry which is mostly liquid. Though the use of bioenergy has caught the attention of many in the recent two decades, biofuels have been in use initially especially in the developing countries where biomass sources such as firewood, animal dung, and charcoal among others have been considered
to be cheaper than other fuels [37]. Initially, biofuel was used in homes only through the use of wood pellets and fuelwood just to mention a few. The other category is the secondary biofuels which are the processed biomass, and they include ethanol as well as biodiesel which can be for industrial purposes and in the vehicle and aviation industry [17].

![Figure 2: Global energy demand by source](image)

1.2 Definition and History of Aviation

The term aviation was first used in the year 1863 by a former French naval officer and writer, Gabrielle La Landelle who coined it from the word avier which is a verb meaning flying and he added the suffix -ation [38]. The origin of the word is a Latin word which means bird, and he added the suffix to form what is now known as aviation meaning anything related to aircraft including the production, design, and development as well as the use and operation of the airplanes. The term aviation is particularly used to mean the heavier-than-air-aircraft machines utilized in the world today for different
purposes. The most significant history of aviation is attributed to the Wright brothers who were the first to develop and fly a flight that was both powered and controlled in December 1903, unlike the ones in the past that had either of the characteristics [38]. The perfection of their design continued for the next one decade with the first plane to carry a passenger being in May 1908 when the Wright brothers carried their mechanic and some cargos as part of the test. By the beginning of the World War I, the aircraft had become fully functional, and they were used in different capacities in the war. The best aircraft to be developed was the Graf Zeppelin, and it was tested in 1929 [19]. The plane was better than those of its time since could fly for one million miles while the rest were flying a few hundred miles.

1.3 Manufacture of Biofuels

Even though the biofuels are known to have an advantage over the fossil fuels, its production requires a lot of consideration before it starts to be produced in large quantities or before it fully takes over the energy industry. The main reasons are because very little is known about the viability as well as high costs of production due to scarce raw materials. The primary focus is on the viability to ensure that it fulfills the goal of providing the energy gain and there will be no energy vacuum or shortage due to a shortage in the supply. Secondly, biofuels are at times produced from crops which can be used in human foods. It is, therefore, paramount to ensure that there is enough food supply and not everything is directed towards the energy industry leaving the world population to starve [47]. In dealing with the problem, the manufacturers should therefore target the second generation biofuel. Unlike the first generation biofuel which is produced from feedstocks that can be used for human consumption, the second generation biofuel feedstocks cannot be consumed by human beings. The third target in the manufacturing of the fuels is to ensure that it will bring greater economic gains compared to the fossil fuels. One of the reasons for shifting focus to the alternative fuels is due to the unstable prices of fossil fuels in the market. Hence, the green energy should provide stability and the economic gain expected [47].

Failure to achieve the objective economic gain will make the efforts just another experiment that will remain in the laboratory since no one will want to increase their cost of operations. The last and the
most significant reason for the manufacture of this fuel is the environmental aspects [47]. Biofuels are known for their environmental benefits making it one of the prime reasons why the stakeholders in the aviation industry are joining the rest of the globe and agreeing that green energy is the way to go.

The previously mentioned area of focus which is the first generation biofuel feedstock is used as the criteria in the manufacturing of the biofuels around the world. Using the above criteria, the primary challenge of fully relying on the biofuels remains in the quantity of production in addition to the quality of the fuel produced. According to experts, the sustainable energy can currently cater for only 12% of the total energy produced by the fossil fuels making the complete shifting somehow a challenge at the moment [21]. Other problems remain one is that large manufacturing of the first generation biofuel will be a threat to the food shortage at the moment. Additionally, until recently where the petroleum prices have started fluctuating due to the instability in the world, the manufacturing of the biofuels is estimated to be much higher than that of the fossil fuels [21]. Therefore, unless the cost of production of biofuel is equal to or lower than the fossil fuels, the aircraft operators will always prefer the fossil fuels as it will reduce their operating costs.

1.4 Biofuel in Aviation

The argument by environmental experts is that if the aviation industry were a single country on its own, it would be the largest contributor of greenhouse gases as it contributes approximately 2% of the gases emitted [14]. The estimation of the emission is, however, not clear with a report from European Commission claiming that the civil aviation alone contributes to 3% of the gases emitted. With the airline industry being one of the fastest growing industries with an estimated consumption of approximately 10% of the total world energy [15], the worry is that the emissions will continue to increase if the necessary measures are not put in place. In Europe alone, the air transport within the member countries account for approximately 14. 5% of the energy consumed by the transportation industry, and it corresponded to about 50 Mtoe that was consumed in the year 2013 [15].
Before the wake of alternative sources of fuel in the aviation industry, Jet fuel was traditionally made from hydrocarbons and was almost exclusive from a fraction of kerosene produced from the crude oil [15]. Since the aviation fuel is very stringent, the only two types of the fuels used are the Jet A and Jet A-1 types where the difference is that the latter freezes at much lower temperatures than the former making Jet A-1 most preferred for the flights flying under extreme conditions such as those in the polar areas [43]. Due to the stringency in the jet fuels, the only alternative fuel to kerosene that has low CO$_2$ emission are the biofuels. And that is the reason why the stakeholder are working round the clock to develop the sector with the primary focus being on the gaseous fuel and electrification as the alternative to meet the standards and ensure safety [15].

![Figure 3: Global energy consumption in the transport industry [15].](image)

### 1.5 Alternative Fuels for Aviation

Given the contribution of the aviation sector to the global CO$_2$ environmentalists believe that introduction of biofuel will play a fundamental role in meeting the international climate change goals that
were laid out in the Paris agreement in 2015 [14]. Various aircraft manufacturers and service providers among other interested parties have committed themselves towards the mission where they are aiming at carbon-neutral growth by the year 2020 and further reducing the emissions to the GHG by approximately 50% by the year 2050 [14]. To achieve their target, the concerned parties are aiming at restructuring the airports, increasing the fuel efficiency of the brand new aircraft as well as aircraft modification which they believe would help to reduce the emissions by 1.5% every year. Biojet is being considered as the only option since there are many uncertainties such as reliability and safety in other technologies that are in development such as the electric and solar powered aircraft which will only be put to use by around the year 2050 making them a delayed option [14]. According to studies, bio jet fuels have high chances of reducing the emissions, and their reduction range from 50% to 95% depending on the feedstock and the source. Either way, it will help in achieving the year 2050 GHG emission reduction target making it a reality [14].

![Figure 4: Contributions of aviation industry towards achieving global target of CO2 emission reduction](24)
Another study referred to by the European Commission showed that in the year 2013 only the aviation industry consumed around 1.5 billion of Jet A-1 fuel and consequentially produced approximately over 700 million metric tons of CO₂ which are equivalent to almost 2% of the total world emissions [12]. The prediction is that since the aviation sector is growing at more than 5% every year, if the emissions grow at a constant rate, then the CO₂ emitted will be six times more by the year 2050 [12]. Europe is one of the vast continents with the most passenger flights and a high number of commercial airlines. As a result, most nations in Europe are on the forefront to campaign for the transition and adoption of the sustainable energy.

Though biofuel in the aviation has been researched for a while now, the change is a bit slow due to the specifications and required standards of the fuels. The aviation industries is one of the most delicate and dangerous sectors, and safety is of utmost importance [8]. For that reason, any new change being introduced has to be tested thoroughly with various requirements being observed to ensure that there are no threats to the aircrafts as well as the passengers. Furthermore, aircraft are quite expensive, and the airlines would like to use them for an extended period. Hence, they have to ensure that the fuel is properly tested and it will not be a threat to their investment by ruining their aircraft. In other words, the aviation industry is looking for an alternative fuel that will directly replace the current jet fuels without compromising on the safety as well as providing high-performance fuel are stringent requirements of the jet fuels [1].

The other reason for the transition from the fossil fuels to the biofuels is their availability. Currently, the crude oil is only found in various locations around the world. Hence, countries have to depend on the suppliers who at times might be a problem since most of the countries are located in the war zones [1]. Furthermore, the demand and supply of the crude oil affect the price which at times goes too high to the extent of requiring interventions from the governments. According to the aircraft operators, fuel is one of the largest operating cost in the sector and, therefore, slightly changing the prices makes it impossible for the firms to budget for the long term. Biofuels are produced from biomass and
plants that can be grown anywhere in the world. Hence, it will be readily available from around the globe. Though the same method of supply as the petroleum will be used for the provision of the biofuels, the fact that it can be grown in almost every part of the world will reduce the possibilities of the suppliers to fluctuate the prices.

2.0 Global Initiatives in Sustainable Aviation

Europe

There is no doubt the different researchers have agreed that the aviation industry is first growing with IATA fact sheet putting it at 5% annually by the year 2030 [24]. The demand for the aviation fuels is expected to increase by between 1.5% and 3% according to International Energy Agency [26]. In the same prospect, the EU expects the air transport industry to grow by approximately 3% annually in the continent until the year 2050, with expected fuel consumption growth of up to 2% per year [32]. One of the main policy and initiatives that guide the production and consumption of the biofuels being the EU member are the White paper with the aim of reaching a share of 40% reduction in the reduction of GHG emissions by the year 2050. The White Paper is a roadmap focusing on the provision of a Single European Transportation Area.

Another group called the High-Level Aviation Group has also come up with their target and an ambitious one which sets the reduction of the GHG emission at 75% in CO$_2$ and 90% in the nitrogen oxides by the year of 2050. Both of the initiatives are in Europe and are aimed at proving the strategy by the EU of making the continent a good example and a leader in the endorsement of the alternative energy and consequentially in the environmental conservation as per the European energy policy [15]. On its part, IATA has committed itself to the same efforts of alternative energy aiming at the growth of the carbon neutral bioenergy by the year 2020 and the targeted CO$_2$ reduction of 50% by the year 2050 [24].
The EC has joined hands with the Airbus and major European airlines as well as leading energy biofuel providers in the same content such as the Neste and UOP in launching an initiative that will push for fast commercialization of the biofuels in the Europe. The air service providers in the initiative include the British Airways and Air France as well as the KLM and Lufthansa. The other energy provider involved in the same is the Biomass Technology Group [15].

Still, in Europe another initiative with voluntary membership committee was formed with the mandate of providing the roadmap for the targeted production of 2 million tons of continuous sustainable energy for the aviation industry annually by the year 2020 [32]. Some of the expected drivers with the greatest impact on the biofuel production according to the IEA Bioenergy 2012 include the overall demand for the jet fuel especially with the constant growth in the aviation industry. The second driver will be the availability of the bio jet fuel, and this focuses on the capability of production, logistics as well as the necessary technology and infrastructure [33]. The third driver will be how it helps in the conservation of the environment regarding the contribution to the GHG effects and whether it is helping in achieving the targeted reduction of CO$_2$ emissions. Further, the market development will be a contributing factor in the price of the oil prices compared to the bio jet fuel prices [32]. Lastly, international trade will also play a fundamental role in the required standards and certification.

**The North & South America**

The continents of America have also come up with initiatives of sustainable energy. In 2011, the IDB launched an initiative in the region of Latin America and broader Caribbean to support cooperation of both the public and the provider sector in the investment of the alternative sustainable bio jet fuels [27]. The purpose of the initiative is to fund all efforts that are related to the sustainable use and the production of the alternative energy which includes the consultancy services, development of knowledge as well as workshops and material dissemination targeting both the local market and also exports to the international market. The IDB partnered with various aviation stakeholders such as the local airlines and aircraft manufacturers as well as international organizations such as ICAO, CAAFI, and the World Economic
Forum. The primary objective of the initiative is to ensure reduction of the CO\textsubscript{2} emission and also to replace 50\% of the current jet fuels with alternative sources by the year 2050 [27].

In another American initiative, aircraft manufacturer Boeing in conjunction with Alaska Airlines and the Port of Seattle signed an agreement in December 2015. The agreement was to launch a joint study aiming at long-term production and utilization of the sustainable jet fuel in and out of the Sea-Tac International Airport. The feasibility study on the infrastructure cost $250,000, and it was expected to be finished by the end of 2016 [31]. The primary objective was to examine the costs as well as the upgrades that will be needed in the airport creating a system delivering a blend of the conventional jet fuels and the aviation biofuel [31]. Though there was fear that the demand for the biofuel will be low since the conventional prices had hit an 11-years low on the price [49], there were still hopes on the bioenergy due to the volatility of the prices of the petroleum making them unpredictable.

Other companies in the United States have signed similar agreements with FedEx, and the Southwest Airlines have signed the agreement with a company that specializes in biorefinery in Oregon in the year 2014 [31]. Red Rock Biofuels which is a company based in Colorado said that it would produce 12 million gal/year of the alternative fuels from the dry 140,000 dry tons of feedstock harvested from forests [31]. The agreement, FedEx committed itself to take 48m gallons by the beginning of the year 2017, to its hub in Oregon. The product will be a 50/50 mix of the biofuel and the conventional fuels [48]. On its part, Southwest agreement was to purchase 3 million gallons per year, and the first batch was extensively expected to be delivered by the end of 2016 [31].

The United States will also have a part to play as it is involved in most of these initiatives through the United States Department of Energy as well as US Navy and the USDA. Further, the FAA is aiming at the United States aviation industry to use 1billion gallons a year of the bio jet fuel by the year 2018. On June 2015, EPA had proposed to include the jet fuel in the Clean Air Act which would make it a contributor to the GHG [31].
**Canada**

The Canadian Government is one of the fully committed governments around the world to ensure that the experiment on the alternative source of energy is fully explored. Through its Renewable Fuel Regulations, the government is targeting to reduce the GHG emission levels of the year 2005 by 17% by the year 2020 [34]. There are several Canadian Federal Government programs aimed towards achieving the success of the alternative fuels programs. Some of the programs include the NRDDI which was formed in the year 2008 to address any questions concerning the use of the biofuels and demonstrate how the projects will operate under the government regulations. Others include the ecoEnergy for Biofuels as well as Next-Generation Funds and ecoAgriculture Biofuels Capital Initiatives [34]. Some of the programs are aimed at supporting any efforts that would lead to production and testing of the biofuels as an alternative source of energy.

According to the Global Agricultural Information Network, a federal mandate in Canada requires that 5% of the national gasoline to be from a renewable energy and in this case ethanol is the most used [13]. Furthermore, the mandate requires that the diesel fuel contains 2% of renewable sources. Besides, although almost every province has adopted the terms, some of the provinces such as the Ontario, Saskatchewan, and Manitoba are adopting higher rates, 5%, 7.5% and 8.5% respectively [13]. The report also indicates that Canada is one of the largest producers of ethanol with figures standing at 1.725bn liters in the year 2015 and there was an expected increase in the year 2016 to 1.75billion liters. However, the quantity is still not enough. Therefore, Canada has to import approximately 1billion liters per annum most of which came from the United States [13].

**China**

In 2010, China was reported to have signed an agreement with commercial aircraft manufacturer Boeing with the aim of establishing sustainable biofuel industries in China [6]. The primary goal of the project was to explore all the aspects of the sustainable biofuel development in the aviation which incorporated the costs of production as well as lifecycle emission analysis, government policies and
The parties to the agreement were the Boeing and the vast PetroChina with representatives from the energy sector in China as well as the global aviation industry. Another arrangement that followed included that of Boeing Research and Technology with QIBEBT which was focused on establishing a laboratory to research on the production of the biofuel feedstocks [6][7].

**Middle East**

Similar efforts are also being carried out in the Middle East with Dubai being on the forefront in the commitment of production of clean and alternative energy for the aviation industry. By 2015, there was already an experiment being conducted in the desert of Abu Dhabi to produce the biofuel feedstocks using the sea water irrigations and the construction of the world's first bio-energy pilot plant was still underway in the desert [29]. The project was being conducted by SBRC which is a non-profit group that was formed in the year 2011 with the initial members being the Etihad, Boeing, and UOP. The membership expanded later when they were joined by Safran as well as GE and Takreer [29].

**Australia and New Zealand**

In 2016, the official air service providers, the Air New Zealand and the Virgin Australia, linked together to investigate whether there was a possibility to locally produce an environmentally-friendly biofuel that would be enough for their supply without shortage [44]. In the New Zealand alone, reports show the emissions from the transport industry account for 17% while an approximated 6% come from the domestic emissions [45]. Just like the rest of the world, the South Pacific countries are making an effort to ensure that they invest in the clean energy and thus protect the world for the GHG pollutions. The two airlines issues are RFI, and one year later they reported to have received positive feedback from organizations both locally and internationally. In Australia, a study carried out by CSIRO concluded that it was possible to achieve a 5% share of bio jet fuel in the two countries by the year 2020 (22). The share was expected to expand to 40% by the year 2050 depending on the both countries' efforts on the sector (22).
3.0 Countries that have Adopted Biofuel in Aviation

Though there are no countries that have completely shifted to the use of the alternative source of energy, several nations as well as airlines have been testing the fuel with others gradually transitioning to the sustainable energy. Some of the countries include;

3.1 The North & South America

Brazil

In 2012, Brazil announces that it was ready to do their first test on the biofuels. The test was to be carried out by Azul Embraer aircraft, and it was to take place in Rio De Janeiro in the Rio+20 United Nations Conference whose main agenda was on sustainable development [30]. The test was made on biofuel produced by Amyris from the feedstock of sugarcane. Additionally, the fuel was believed to have been approved having undergone all the requirements and certification for the bio jet fuels which include fit-for-purpose properties as well as reduction of GHG emissions. Also, the fuel had passed the test to replace the conventional fuels of Jet A and Jet A-1 types and was ready for testing [30]. The test was a great achievement especially since Azul is one of the largest airlines in Brazil.
Canada

In 2012, the Porter Airlines which is one of the country's air service provider announced that it had finally succeeded in flight its first aircraft Bombardier Q400 marking the success of a program that started in the year 2010 [5]. The test flight took off from Toronto to Ottawa using a jet fuel that was a 50/50 blend of the conventional fuels and a biofuel in its engines [30].

The United States

In the United States, various tests have been conducted by airlines and aircraft manufacturers. On the many airlines that adopt biofuel is the American Airline, which announces that it was to carry out its first flight test using the biofuels. The test was to be done on Boeing ecoDemostrator aircraft [30]. During the same period, the air service provider signed agreements with two biofuel suppliers. In Alaska, the same efforts were underway, though the Alaska Airlines said they would not be able to transition to the green energy due to the inadequate supplies make the bio jet fuel unreliable [30]. The airline was also faced with the challenge in the process of accessing the fuel as it was being produced in the State of Louisiana the refined in the State of Texas and then later sourced to Alaska by the Netherlands who act as the brokers. Different stakeholders in the aviation industry such as the Honeywell's UOP which is an energy provider, United Airlines which is an American air service provider, as well as Clean Energy Trust, came together in the year 2012 to announce the formation of MASBI [8]. Other members included the Boeing which is an aircraft manufacturer and Chicago Department of Aviation. The main agenda of the MASBI was to explore the sector of biofuel as an alternative source of energy in aviation [30].

3.2 Europe, Middle East, and Africa

In Europe, similar activities were carried out within most of the countries making milestone progress in the sustainable energy sector. In 2011, Algae Tech. Ltd signed an MOU with exclusively one of the primary leading airlines in the continent the Lufthansa to jointly analyze the algae oil from the company bio-reactors and develop it into a prolonged sustainable source of alternative energy [2][46]. However, in January 2012, Lufthansa primarily announced that its flight to Washington from Frankfurt
would be its last using the biofuel since they had not yet secured a reliable supply of the biofuel that would be utilized for a long-term [30]. Nonetheless, the country's aviation industry acknowledged it had managed to reduce the carbon emissions by 1,147 tons from the 1,187 flights that had been operated in the country so far [30]. The consumption of the mix the biokerosene was 1,556, and various aircraft manufacturers as air service providers acknowledged that their aviation engines operated excellently with the green energy compared to the conventional one.

During the same period, Air France which is a major air service provider in France announced that it had successfully operated its first passenger flight using the renewable energy. The flight was running a 50/50 mix on the convention jet fuel and also the jet fuel that had been produced from utilized cooking oil [30]. According to the air traffic management, the Air France flight managed to cut down the CO₂ emission by 50%, and it helped to reduce the emission per traveler to 54g per kilometer [30].

In the UK, Virgin Atlantic reported that it had linked with LanzaTech in a project to produce biojet fuel that will first target its two destinations in Asia which are Shanghai and Delhi [16]. The reason for focusing on the two destinations is because LanzaTech had been working on the fuel production in China and India, and, therefore it was easier to do the implementation of the program in the continent [30]. The two companies said they expected to bring Boeing on board in their trial phase. Though the pilot project was being carried out in New Zealand, the larger demonstration was to be made in Shanghai in the year 2013, while the first commercial flight took place in China the following year [9]. Other flights that had announced to test the program was the Thomson Airways with its first flight said to take off from Birmingham en route to Arecife in Spain. The flight would use a 50/50 mixture of biofuel produced from utilized cooking oil and the regular jet fuels [30].

Other tests that were scheduled to be made in Europe around the same period include those of Finnair from Finland which was to run on biofuel produced by SkyNRG [36]. The test was to be conducted on Airbus scheduled from Amsterdam to Helsinki. In Netherlands, KLM became the first
commercial flight around the world to operate on green energy carrying 171 passengers on board. Fuel was continuously supplied by Dynamic Fuels through the SkyNRG [30].

The Middle East and Africa were also not left behind with Qatar Airways reported having been interested in investing 10% in Byogy Renewables, a Californian firm that specializes in the production of the biofuels [30]. In UAE, Etihad airlines had already accepted the delivery of a Boeing 777-300ER aircraft that flew from Seattle to Abu Dhabi incorporating the biofuel and making it the first complete flight of such kind on the Gulf of Persia [4]. In Africa, South African Airlines announced that it would have to utilize 50% biofuels in its flights to avoid the penalties as a result of carbon emissions [33].
4.0 Challenges Facing the Biofuel in Aviation

In spite of the positive results from the use of biofuel as the alternative source of energy in aviation, the sector is confronted with some challenges that might delay or threaten its full adoption.
4.1 Economics of Production

First, the issue of the production economics where it is expected to be cheaper or at the same rate with the other convention fuels. On the contrary, several studies have proved biofuel to be more expensive than fossil fuels [10]. According to the information from the aviation industry, Jet fuel is one of the biggest operating cost as of December 2016, and it accounts for approximately 18% of the airline costs [24]. Any increase in the fuel prices will significantly increase the operating expenses of the airlines, and therefore might not be accepted. According to another recent research, statistics showed that an increase in $ 1 per barrel would raise the operating cost of an airline companies by $ 425 million [11]. For the alternative jet fuels to replace the conventional ones, the cost of production must be equal or lower, and that will only be possible if there is a stable supply of the feedstocks.

![Figure 7: Comparison between Conventional Fuels and Biofuel Prices](image)

Currently, the cost of production of the alternative fuels is not clear since there are a lot of disparities with the cost estimates ranging from $ 2 to over $ 10 per gallon [11]. The variations depend on the availability of the process of production which varies from one feedstock to another, the performance
of the fuel and also the plant scale. Several other assumptions are made when estimating the cost of the green energy which makes it a challenge for the aviation industry. The issue of inconsistencies from the studies that are expected to give the prices makes it a limitation for the aviation industry stakeholders to invest in the sector.

4.2 Resource Availability

The production cost of the alternative biofuel highly depends on the availability which is currently a major challenge to overcome. The efforts to lower the prices of green energy and increase the market supply could only be achieved if there is enough production of the feedstock particularly the lignocellulose [3]. Currently, the largest amount of biofuels are produced from used cooking oils as well as animal wastes and vegetable oils, but the production is not sufficient with predictions that the productions will only increase by 8% from the current 3.8 to 4.1 tons per year [32]. Most of the fuel production made in the year 2014 amounting to approximately 290 million tons was from feedstocks such as animal wastes and wood pellets that cannot be developed for future production [32]. Additionally, this means that sources will be limited in future, and therefore future sources of alternative jet fuel are uncertain. The uncertainties can, however, be addressed by providing the investors that there are efforts to grow other feedstocks that will give certainty for the investment.

4.3 Technology deployment and Financing

The sector of the alternative jet fuel is very new in the aviation and is faced with several uncertainties. Though there have been a lot of research made in the area, there are fears of investing more in scaling up the production and many programs are still stuck in their pilot phase [30]. Setting up production plants require a lot of capital and many stakeholders are only ready to do so if the industry is full development or else they risk investing in white elephant projects. Also, there is a lot that is still not known concerning the production, and therefore, there is much more to be made regarding technology to ensure sustainable production.
4.4 Certification

The other area of challenge in the AJF is the certification process which is lengthy and costly. The aviation industry is one of the riskiest sectors, and therefore, it involves a lot of requirements before a new product is approved for safety purpose [18]. According to those who have already went through the process of certification with ASTM, it takes between 3 to 5 years at a very high cost of between 10 to 15 million USD [32]. From the numbers presented regarding the time taken and the costs, there is a significant need for both to be reviewed as it is scaring away the interested stakeholders.

5.0 Need for Government Support

The main agenda of the biofuel in aviation is the transition from the current fossil fuels that are not extensively friendly to the environment, to the use of clean energy to reduce the GHG emissions. The effort is, however, challenged by the high cost of production of the alternative jet fuel making the investor prefer the conventional fuels [40]. Therefore, this hinders the achievements of global targets in the reduction of the carbon emissions. IATA on its part has requested the governments to intervene and provide support regarding reducing the costs as well as coming up with the policies that will encourage production of the green energy [42]. Some of the governments such as the Canadian and the United States are already actively involved in the efforts through their departments of agriculture, technology, and energy.

Though biofuels have been proven to be better than the conventional fuels, the world is not ready to replace the fossil fuels due to several reasons. One of the reasons is that there is not enough production of feedstocks required to produce, nor equivalent of the conventional fuels used in the world. The government should intervene in doing research on how to increase the production of the raw materials as well as give incentives to private sectors which are interested in the same field to ensure maximum production. With enough supply of raw materials, the price of bioenergy will go down due to reduction in uncertainties and reduced cost of production [41].
Despite the effort by the governments to comment positively on the production of the biofuels, some aviation stakeholders feel it is not enough and the government needs to do more to share the burden [23]. For instance, in September 2014, when Finnair fuel their flight to New York for a Climate Summit, the Finnish Government supported the efforts through positive comments [23]. However Finnair, although they appreciated the comment, the airline felt that the government needed to do more.

6.0 Conclusion

The recent studies have placed aviation industry among the top contributors of GHG emissions world [39]. According to the statistics, the sector contributes approximate 3% of all the carbon emissions produced, with experts claiming that it would have the single highest contributor if it were an individual nation [12]. With the current efforts by the world governments and organization to reduce the effects of global warming cutting down the emission of carbon and nitrogen gases, the focus has been on the introduction of clean energy in the aviation industry.

Production of biofuels to be used in the aircraft as an alternative source of energy is believed to be the best option for the industry. Several tests have been made, and success recorded all over the world with the continents making major progress being North and South America as well as Europe [21]. Some of the stakeholders in the efforts include the aircraft manufacturers such as Boeing and Airbus, various air service providers such as the British Airways, Etihad, Qatar Airways, also KLM Royal Dutch Airlines as well as Air France and United Airlines among others. The efforts have also involved several energy providers who include the SkyNRG, Neste and Honeywell's UOP just to mention a few [34].

Moreover, though there are several benefits from the use of the alternative jet fuels, there are some challenges that are threatening the growth and the transition from the current fossil fuels to the clean energy [35]. Some of the challenges include the uncertainty of the supply of the feedstock which is currently very low, the process of certification to test the program regarding time and cost as well as the finances involved in the transition [26]. Finally, various stakeholders have therefore asked the
governments to intervene by providing subsidies and favorable policies for the industry to grow. The report concluded that biofuel is a viable option in the aviation sector since the tests made have given positive results. Therefore, it is upon the stakeholders in the industry which include aircraft manufacturers, airline service providers as well as the governments to support each other in the transition process.
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