Feasibility of Second and Third Generation Biofuel in General Aviation: A Research Report and Analysis

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Feasibility of Second and Third Generation Biofuel in General Aviation

A Research Report and Analysis

John A. Christian, II
Abstract

This research paper examines the feasibility for second-generation biofuels as an alternative fuel supply for both piston- and turbine-powered general aviation aircraft. With relevant research given to the history of biofuels and their technologic development, this paper aims to provide an analysis of biofuel development, biofuel technology and its potential impacts, specifically for the aviation industry.

Multiple industry and international studies are reviewed in support of the feasibility of second-generation biofuels as an alternative for the general aviation industry. Current industry activities and technological developments were reviewed to set a baseline for biofuel development and application. It is found that there is increasing interest in biofuel technology and ample support for research and design of biofuel as it pertains to the aviation industry.

Industry leaders have created multiple initiatives, consortiums and action groups in an effort to further the research and development of biofuel technology. The whole value chain of biofuel, including scientists, investors, aviation leaders, manufacturers and production have been involved in the movement to find an alternative to conventional aviation fuel. This is brought on by the demand for diminishing rising commercial aviation expenditures and reducing the carbon footprint of the aviation industry.

General aviation leaders have taken a vested interest in converting current aircraft to diesel engines in an effort to bring biofuels into the general aviation community. Additional developments conducted by industry manufacturers have moved towards offering diesel-powered aircrafts as options. This change actually offers a reduction in lifetime fuel costs and an opportunity to use
biodiesel fuel. The feasibility of using second- or third-generation biofuel is
dependent on the economic and industrial transition

Biofuels: History

The rise of gas prices in America has led to research and testing for
alternative fuel sources. Research has been done in the areas of hybrid and clean
fuel sources as a way to have fuels more environmentally friendly, sustainable,
and less expensive option for the consumer. Currently, conventional fuels
include fossil fuels (petroleum/oil, coal, propane, and natural gas), nuclear
materials, and artificial radioisotope fuels (made in nuclear reactors).

Alternative fuel is known as a fuel other than gasoline for powering motor
vehicles. Alternative fuels include bio alcohol, hydrogen, bio diesel, non-fossil
natural gas, and biomass. While major advancements have been made for the
automotive industry, mostly on the side of hybrids, little progress has been made
in regards to aviation, more specifically General Aviation (GA). Most GA aircraft
have piston engines that are fueled by 100LL aviation gasoline. The price of this
specialized gasoline for airplanes typically ranges from $2.00 - $4.00; more
expensive than automotive gasoline due to the refining process and the additives
in 100LL. As the owners of GA aircraft battle with the increasing gas prices, they
are deciding to fly less and hope for options that will reduce the cost of flying.

Due to the rising cost of aviation gas, the future of petroleum-based fuel in
GA is not sustainable and other fuel options must be pursued. While hybrid
technology can be used in the automotive industry, the principles in hybrid
technology (regenerative breaking, electric motor drive/assist, and automatic
start/shutoff) are problematic when considering the applicability for use in flight
due to the nature of flying and the need of the engine running constantly. While
there is research being done in the field of aviation for a hybrid model, it does not present a viable option for general aviation. Therefore, alternative fuels are the option that presents the most viable substitute.

There are many different possibilities to pursue for alternative fuels, but the area that shows the most promise is biofuels. Biofuels are renewable, clean burning, and efficient. Biofuels are made from organic matter through fermentation or extraction. The history of biofuels dates back to the 1820s, which was a blend of camphene and alcohol used for lamps. At that time “as much as 100 million gallons a year were sold” (Siegel, 2012).

From the 1820’s the competition between biofuels and fossil fuels has been ongoing. The first combustion engines were designed to run off biofuels. The reasoning behind fossil fuels being more prominent is unknown, but the prevailing theory is because of government legislation and taxes. This is shown in the article, the future of biofuels, by Siegel (2012) where he speaks about the history of biofuels and talks about government taxing, “…in 1862, when a $2 per gallon tax was assessed on alcohol to help finance the Civil War. But somehow, kerosene, or coal oil, as it was called then, was taxed at only ten cents a gallon. By 1870, kerosene was selling over 200 million gallons a year. The alcohol tax was repealed in 1906 by Teddy Roosevelt…”. By the time the tax was repealed fossil fuels had already been too ingrained in to daily American life, and it would not have been cost effective to switch to biofuels. The competition between fossil fuels and biofuels has stretched through out American history to today. The debate always arises when gasoline prices begin to increase.

**Biofuels: A Definition**

Biofuel production reduces our dependency on fossil fuels while expanding and diversifying our domestic refinery capacities. By definition, biofuels are mainly derived from biomass or biowaste, and can often be mixed with other elements such as diesel, to create a source of power. A biofuel is a hydrocarbon that is made “by” or “from” a living organism, that is in turn, used
to power something. Though there are ample uses for biofuels, the concentration of this paper, like the concentration of the biofuel industry, is transportation.

Most largely available commercial vehicles operate with engines that require dense, high-power producing fuels, or a high-energy yield. Liquid fuel is currently the most widely popular and available choice of fuel type for most modes of transportation, credited to its easy transferring, pumping and storage characteristics.

The push for biofuels comes with the increased need to address rising fuel prices, sustainability, and reducing emissions of greenhouse gases. Most importantly, the mass production of biofuels offers energy security against depleting non-renewable fossil fuel resources. This directly translates to having an impact on the aviation industry, both commercial and general. The carbon footprint left behind by commercial and general aviation nearly matches that of the momentous fuel bills associated with aviation.

The production and growing acceptance of biofuel as a major fuel contender is global. Currently, North America, Europe, and Asia are major supporters of biofuel technology research and are growing producers and users of biofuel. However, it is the limitations presented by first-generation biofuels that have ignited the need for research and development in second-generation biofuels.

Like all developing technologies, there are many different generations of biofuel. However, it is important to note that the structure of biofuel itself does not change from generation to generation. The only thing that changes is the source from which the biofuel is extracted. Each presenting its own advantages and disadvantages, first, second and third generation biofuels are defined and examined to set the framework of this research in an effort to distinguish feasibility.

**First Generation Biofuels**

The start of the biofuel movement came with the first generation of alternative fuel sources, harvested directly from edible agricultural food sources.
First generation liquid biofuel can come from a number of edible resources including: starches, sugars, animal fats, and vegetable oils. Globally, sugar cane, wheat, and corn stock are the most commonly used feed stock source for first-generation biofuel. Sugar beets, rapeseed and peanuts were also once considered a plausible source for first-generation biofuels.

According to the United Kingdom’s Biofuel Organization, the most common types of first generation biofuel used to date are ethanol, biodiesel, vegetable oil, biogas, bioalcohols and syngas. Each of these biofuels are sourced from feed stock and have been used for transportation. Biodiesel, ethanol and vegetable oils are among the leading first-generation alternative for transportation.

Biodiesel is most commonly used throughout Europe and in the United States as an alternative means for transportation. It is one of the only commercialized alternatives, and is made more readily available to the average buyer. This particular biofuel is most compatible with current diesel engines. Manufacturers of the diesel engine in the United States and throughout Europe often market their engine products as being compatible with biodiesel.

Ethanol is derived from corn feedstock and has the ability to supply sufficient power. However, the negative impact it holds on the food supply available and the agricultural economy make it a less appealing option as a long-term biofuel solution to fossil fuels.

Vegetable oil is derived from various vegetables and is often used in cooking. However, this substance can offer power potential for many uses. It also has the potential to be a gateway fuel into second-generation fuels, as it can be derived from used vegetable oil after cooking. The advantage of utilizing unused or uncooked vegetable oil, is that it is easily converted to biodiesel and can power a diesel engine, with little modification to the engine.

Embry-Riddle Aeronautical University’s Mechanical Engineering student, Michelle Rodio created the university’s very own biodiesel station on the Daytona Beach Campus. Using part virgin and sometimes part used vegetable waste oil, Rodio was able to create biodiesel to fuel various Embry-Riddle vehicles on campus and contribute to the Department of Energy’s EcoCAR 2
green energy competition ERAU was competing in. Below is a diagram of how biodiesel can be made from vegetable oil as the biofuel source.

Image: Michelle Rodio, Biodiesel Lifecycle, Embry-Riddle Aeronautical University, 2012.

Although there has been proven success in first-generation technology, there are many difficulties to overcome with this generation of biofuels. In a report published by the International Energy Agency, the IEA’s “Overview of 1\textsuperscript{st} and 2\textsuperscript{nd} generation biofuel technologies and current industry activities” (Sims, 2008) spelled out a less than feasible outlook for the first-generation.

The IEA is an autonomous body, which was established in 1974 to implement an international energy program. IEA is made up of 29 participating member countries, including the United States, the United Kingdom, Australia,
Canada, New Zealand and Japan. The IEA has paid careful attention to the development of biofuels, the benefits of each alternative and the obstacles that stand in the way of mass production and global acceptance of a fossil fuel alternative.

“It is increasingly understood that 1st-generation biofuels (produced primarily from food crops such as grains, sugar beet and oil seeds) are limited in their ability to achieve target oil-product substitution, climate change mitigation, and economic growth,” concluded the report, “Their sustainable production is under review, as is the possibility of creating undue competition for land and water used for food and fiber production,” (Sims, 2008).

The concern of using food sources for biofuel production stem from the fear of decreased food production for edibility, not biofuel production. The issue of rising food prices is also a concern due to competition. With many countries unable to supply a sufficient amount of food as it is, the IEA determined that the “cumulative impacts of these concerns have increased the interest in developing biofuels produced from non-food biomass.”

In their report, the IEA examines non-food biomass sources such as “lingo-cellulosic materials, including cereal straw, bagasse, forest residues, and purpose-grown energy crops such as vegetable grasses and short rotation forests.” Municipal waste and sustainable non-food biomass resources are also a favorable extract for second-generation biofuels. Overall, the sustainable and economic production of first-generation biofuels has come under much criticism.

**Second-Generation Biofuels**

Second generation biofuels are also referred to as “advanced biofuels,” as they are still currently in the research and development phases. These biofuels have not been readily made available to the public and the technology is still being refined. What separates them from first generation biofuels is the fact that second-generation biofuels are not made from food crops or edible biomass crops.
This generation of biofuel is made from nonfood feedstock using multiple advanced technical processes. There is one exception to using food crops in second-generation biofuels, and that is when second-generation biofuels are extracted from food wastes. One example of this is utilizing vegetable waste oil that is no longer fit for consumption.

In order to be considered a second-generation biofuel feedstock, a source must not be suitable for human consumption. Another common characteristic of second-generation feedstock is that it is mostly grown on marginal land, or land that is not suitable to produce a food source, according to the UK’s Biofuel Organization.

Common second-generation biofuel sources include lignocellulosic feedstocks, grasses, Jatropha, seed crops, waste vegetable oil, and municipal solid waste and forest residues. In the United States, the switchgrass is a favored contender among grass feedstocks.

Switchgrass, like other grasses are perennial, which diminishes the cost of repeated planting. Other advantages include rate of growth, ability to work well as direct biomass and possessing a high net energy yield of about 540% according to the UK’s Biofuel Organization. However, grasses are not suitable for producing biodiesel and require extensive phase processing to be converted into ethanol. The water requirement for grasses is the biggest drawback for this second-generation biofuel source.

Jatropha and other seed crops can be used for the production of biodiesel. With a high-energy potential yield per seed, Jatropha is also a candidate for an alternative. Unfortunately, when grown on marginal land, the yield of this plant diminishes substantially, as opposed to being grown on fertile, well-watered land. Today, studies conducted on jatropha, cammelina and rapeseed examine the benefits of the crop and the offsets of investment and land requirements.

Waste vegetable oil has been previously used in many global studies and has been used for more than a century. Some engines are currently capable of running on waste vegetable oil or the biodiesel made from it. Modification kits for personal vehicles are also available to the public. This particular biofuel does not threaten food crops or land usage and is readily available for conversion.
Waste vegetable oil is considered one of the best sources of biodiesel and has potential to meet much of the projected demand for biodiesel in the future. One drawback is the collection of this source, since it is widely distributed throughout the globe in households and restaurants.

Although it has not been converted into a commercialized fuel source, municipal solid waste such as gasses from landfills, human waste and yard waste offer a source of energy. This biofuel offers a smaller carbon footprint than that of fossil fuels and is currently being utilized in some industrial areas to produce heat and electricity.

“These second-generation biofuels could avoid many of the concerns facing first-generation biofuels and potentially offer greater cost reduction potential in the longer term,” (Sims, R. et al, 2008). Technical barriers still exist for harnessing the power of second-generation feedstock and mass production, but it is not impossible. It is feasible to think second-generation feedstock could serve as a suitable alternative. However, much consideration for processing, transfer and distribution logistics is still on the table, according to the IEA.

Third Generation Biofuels

Third-generation biofuel is a fairly recent term in the biofuel world. Third-generation biofuel is made from algae. Algae was previously considered second-generation, until it was determined that algae could produce a much higher energy yield than second-generation biofuel feedstock. Another bonus to algae is that it requires a lot less resource dedication to produce and maintain.

Algae is an up and coming contender for the alternative fuel issue. Not only does algae offer a high-energy yield and a high quantity volume, it also offers diversity. As is, algae can offer a diverse collection of fuel options. A great advantage to algae is that it can be genetically manipulated to create the following types of fuels: biodiesel, gasoline, ethanol, butanol, methane, vegetable oil and jet fuel.

According to the US Department of Energy, algae is capable of producing very high yields. This is an enormous yield compared to other biofuel source
feedstock. If algae were to be commercialized and mass produces, the US Department of energy determined that it would only take about 0.42% of U.S. land area to meet all the fuel needs of the U.S. This is an incredibly attractive notion, since the U.S. is one of the world’s largest fuel consumers.

Algae can be cultivated in open ponds, closed-loop systems and photobioreactors, which give multiple options for the harvesting of this feedstock. Algae can grow anywhere the climate is warm enough. This means that cultivation systems could be set up in desert locations, avoiding using any farm or crop lands.

Additionally, algae can thrive in wastewater and be used to digest municipal waste.
However, there is still much to research about algae. There are drawbacks to this biofuel feedstock. The issue with algae is that even when grown in wastewater, it requires large amounts of water, nitrogen, and phosphorus to grow. The fertilizer required to harvest such a high yield of algae, would produce more greenhouse gas emissions than were saved by using algae based biofuel.

Due to the needs of algae production, the U.S. Department of Energy also predicted the cost of algae based biofuel would be much higher than fuel from other sources. Additional research and development for the production of algae in a mass quantity, without major environmental ramifications needs to be continued. Overall, third-generation biofuels are still under development and research.

As second and third generation biofuels are still being mulled over, a fourth generation is emerging amidst the bioenergy community. Fourth-generation biofuels would involve genetically engineered biomass crops, which produce a high yield and little horticulture requirements.

There have been many discoveries and possible alternatives developed through the different generations of biofuels. However, there is still yet to be an alternative found that does not have hindering ramifications. Continued research and development need to be conducted in order to find an alternative that is renewable, sustainable and does not have a great economic or environmental drawback. It has been suggested that utilizing a combination of biofuel generations would be a viable option for commercialization.

Biofuel Processes and Technologies
There are various ways to extract, create, and mix biofuels. Each generation of biofuel technology is different. Advances in biofuel technology grow more complex in some areas and less complex in others.

First generation biofuels have a fairly simple extraction and production process. Using food crops as the source, fermentation is a large part of the biofuel production. Depending on the end result biofuel, mixing, gasification and compression may also occur during the process. The conversion routes and process for ethanol and biodiesel are well understood and simple compared to that of the emerging processes for second-generation extraction and conversion.

There are two heavily explored pathways to second-generation biofuels discussed in the IEA report: biochemical conversion and thermochemical conversion. However, these are not the only pathways being examined. There are several variations and alternatives under evaluation in research labs and pilot-plants, according to the IEA.

Biochemical conversion involves several biological and chemical processes. It is the process “in which enzymes and other micro-organisms are used to convert cellulose and hemicellulose components of the feedstocks to sugars prior to their fermentation to produce ethanol from lingo-cellulosic feedstocks,” (Sims, R. et al, 2008).

Of the studies examined by the IEA, the biochemical conversion offered a slight smaller energy yield at 6.3 GJ/t, than that of the thermochemical conversion, which produced an energy yield of 6.9 GJ/t. The IEA also determines that much is still to be done in terms of improving feedstock characteristics for biochemical conversion, as well as additional research and development needed to reduce production and pretreatment costs of the biofuel feedstock.

Thermochemical conversion, also know as biomass to liquids (BTL), utilizes gasification and pyrolysis technology to produce syngas. Thermochemical conversion contributed to the approval of current aviation biofuel processing standards. These processes for aviation biofuel will be discussed later in this report.
Gasification is the first type of thermochemical pathway. Though it is not a new technology, second-generation gasification methods have been slightly altered from that of conventional fossil fuel gasification. This is so that it can accommodate differences in biomass feedstock, (Sims, R. et al, 2008).

Gasification allows for the conversion of carbon-based materials to carbon monoxide, carbon dioxide and hydrogen. Oxygen is limited and the resulting gas is referred to as syngas, which is used to generate energy or heat.

Pyrolysis is the second thermochemical pathway that is conducted without oxygen, using an inert gas. Torrefaction is a third pathway and is similar to pyrolysis, but is conducted at cooler temperatures. Torrefaction is often used to convert biofuel feedstock into a more transportable and storable form.
IEA determined that there was “no clear commercial or technical advantage between the biochemical and thermo-chemical pathways, even after many years of RD&D and the development of near-commercial demonstrations. Both technologies remain unproven at the fully commercial scale, are under continual development and evaluation, and have significant technical and environmental barriers yet to be overcome,” (Sims, R., et al, 2008).

The best means for second-generation and third-generation biofuel production is still largely under examination. Though there are pilot-plants in use now for demonstration of mass production capabilities, there are often problems found with the process. Current technologies do allow for mass production, but at a high economic cost. In addition, the negative environmental impacts of producing mass quantities, is often found to be greater than that of the positive impact of biofuel itself. This most often is realized within the automotive sector of transportation.

Another process is the Fischer-Tropsch process (FT). “The FT process occurs through a set of chemical reactions that turn a mixture of carbon monoxide gas and hydrogen gas into liquid hydrocarbons (fossil fuels like gasoline or kerosene),” (U.S. Department of Energy, 2013). The below image from Stanford University depicts the process:
The FT process has been approved in transport and energy producing settings and offers many benefits. The FT process has also proven to make diesel low in sulfur. For aviation fuel, there are two additional approved processing methods: HEFA and BTL.

The HEFA process takes biomass such as “algae, jatropha or camelina and presses it to extract the oils inside, which are then refined into jet fuel in a similar way that crude fossil oil is refined. One of the other outcomes of the pressing process is a leftover substance: the meal. In many cases this meal can also be used. The solid residues left from the processing of jatropha, for example, can be used as fuel for burning on fires and in stoves. The meal from algae oil
production can be used for fertilizer, animal feed and other purposes, and camelina meal can be used as animal feed," (Air Transport Action Group, 2011).

"In the BtL process, the feedstock is broken down through gasification, a process by which the biomass is heated to an extremely high temperature which cracks the molecules and produces a gas. This gas is then converted into liquid jet fuel through the Fischer-Tropsch process, (Air Transport Action Group, 2011). Two other pathways that are being explored in detail for the approval in aviation jet fuel are the Alcohol-to-jet process and the Pyrolosis process.

Biofuel in Aviation:
Currently, there are biofuel options within transportation. The automotive industry has been largely impacted by biofuel research and development. There are vehicles available to the masses that run on different biofuels (ethanol, biodiesel, etc.) and electricity. There are YouTube videos and at home kits available for individuals to convert their gas-powered vehicles to run on vegetable oil, biodiesel and various biomasses. More recently, the same types of developments are being made within the aviation industry, both commercial and general sectors.

Although you do need a Supplemental Type Certificate and approval from the FAA to make any modifications to an aircraft, research and development activities have been increasing in order to address the large impact the aviation industry has on the fuel economy. Airlines, energy groups and manufacturers are taking a vested interest in the research and development of biofuel in the aviation industry and alternatives to expensive avgas bills. There is a high level of support for biofuels in the aviation industry. However, it is important to find an alternative that has the ability to substitute traditional aviation fuel with the same qualities and characteristics needed.
There are multiple economic, environmental and social benefits to utilizing biofuel. The environmental benefits of biofuel have been largely talked about. What some groups are also praising are the social benefits. Creating a new mass industry of biofuel technology, distribution, harvesting and refining creates more jobs and brings the search for power and energy back to the United States, instead of being dependent on foreign oil.

Aviation is the second largest consumer of energy in the transport industry, according to the U.S. Department of Energy. Which is why Delta Airlines purchased their own oil refinery, in an effort to offset fuel costs. The issue with finding a substitution for aviation is the need for a highly pure chemically stable fuel for various plane engines. Due to the nature of this means of transportation, fuel must not be easily manipulated by the conditions it may...
be exposed to. For example, aviation fuel should not freeze easily, as altitudes increase. This makes biofuels for aviation more difficult to produce and the need for alternative engine developments so important.

According to the Air Transport Action Group (2011), developing sustainable biofuels for aviation will enable the industry to reduce its carbon footprint by reducing its greenhouse gas emissions; allow it to draw upon a variety of different fuel sources; be easier to implement than for other transport modes.

Currently there are several European companies who have had success-producing biofuel using jatropha, which meets the needs of the aviation engine. Test flights with airlines and the U.S. military have demonstrated that blends of petroleum-based jet fuel and bio-jet fuel are safe and effective, according to the U.S. Department of Energy.

In the U.S., the California-based alternative energy company SGBiofuels (SGB) has been developing genetically altered versions of jatropha, creating a hybrid jatropha that produces a higher energy yield and a lower economic impact. Using genomic technologies, SGB is able to produce and alter DNA strands that exploit the desirable attributes of the plant.

SGB is a privately owned company, focusing on the biofuel and renewable energy platform. Currently they are working on JETBIO, which is a 75,000 acre project bio jet fuel, led by a consortium with members including Airbus, TAM, Air BP, Bioventures Brasil, Rio Pardo Bioenergio and the Inter-American Development Bank.

Other projects include: GEMINI: a 25,000 acre project in Guatemala funded by SGB investors; FIAGRIL: a hybrid trial center in Brazil with one of Brazil’s largest refiners; and EMBRAPA: a strategic research partnership with leading agricultural research organizations in Brazil. It is SGB’s hope that they soon will be able to provide a sustainable and cost-effective option to Brazil’s aviation industry as well as other countries.

To date, there have been several pilot programs and tests within the U.S. aviation industry involving biofuels. In 2012 the US Air Force certified its F-16s
to fly on biofuel derived from the camelina plant. They have been checked out to fly on a 50/50 blend of hydroprocessed renewable camelina bio-oil and regular JP-8 jet fuel. In a statement issued by the U.S. Air Force, it was said that “as the largest consumer of energy in the Defense Department and $8 billion spent on fuel in fiscal 2011, Air Force officials are working toward making the fleet a little “greener” by researching, testing and ultimately implementing the use of alternative fuels.” (U.S. Air Force, 2012).

Other U.S. Air Force planes have been certified to use biofuel for “unrestricted operations.” One such plane is the C-17 Globemaster III. The USAF has been a strong advocate for fuel alternatives and continues to test new biofuel alternatives on their airframes. However, current fleets cannot operate on biofuel alone and have only had successes utilizing a blend of jet fuel and biofuel. USAF researchers and developers are still working on creating a seamless transition from jet fuel to biofuel.

Midwest Aviation Sustainable Biofuels Initiative

Another leading initiative in the U.S. energy realm is the MASBI group. MASBI is the Midwest Aviation Sustainable Biofuels initiative, made up of industry leaders. MASBI “brings together representatives from across the biofuels value chain to address ways to best leverage regional assets to:

- Become a national leader in the emerging aviation biofuels market;
- Position the Midwest to achieve economic development and job growth;
- Diversify current jet fuel supply in the region and for the nation;
- Promote U.S. energy security; and
- Reduce environmental impact

Through collaboration across public-private entities, MASBI will help achieve the potential economic, environmental, and energy security benefits that can be delivered from a robust advanced biofuels industry,” (masbi.org, 2013).

MASBI’s “steering committee” is made up of industry leaders such as: United Airlines, Boeing, Chicago Department of Aviation, Clean Energy Trust and Honeywell’s UOP.
“The aviation industry has been hard at work to make advanced aviation biofuels a reality. In 2009, ASTM International, the worldwide standards body that establishes jet fuel specification requirements, approved ASTM D7566. This new fuel specification enables the use of fuels from the Fischer-Tropsch (FT) process to be used on aircraft in a blend with conventional jet fuel of up to 50%. In 2011, certification was extended to allow hydroprocessed esters and fatty acids (HEFA) or hydrotreated renewable jet (HRJ) to be used on aircraft also in a blend with conventional jet fuel of up to 50%,” (masbi.org, 2013).

According to ASTM International, all ASTM certified fuels must be “drop-in,” meaning no modifications to the aircraft or equipment are needed for fuel use. “In the few short years since ASTM certification has been achieved, over 1,500 passenger biofuel flights have been flown to date. This includes the first U.S. commercial passenger biofuel flight flown by United Airlines on November 7th, 2011 using algae based advanced biofuel that was blended with traditional jet fuel,” (masbi.org, 2013).

MASBI is focused on the Midwest region of the United States, for its regional natural resources, investment potential and research centers that are already working on biofuel and sustainable energy initiatives. MASBI concentrates on all aspects of the biofuel value chain, but is focused on the aviation industry. The Midwest region alone transports 234 million passengers a year and consumes nearly 3 billion gallons of jet fuel per year.

“Commercial aviation spends $6.3 billion on jet fuel a year for flights originating in the Midwest. MASBI estimates that replacing five percent of petroleum jet fuel in the Midwest with aviation biofuel would create more than 3,600 jobs and reduce carbon-dioxide emissions by 700,000 tons,” (masbi.org, 2013).

There have been several projects and initiatives that developed a strong base for MASBI. Some key initiatives highlighted by MASBI include the following:

- “Farm to Fly: In July 2010, the U.S. Department of Agriculture (USDA), Airlines for America, Inc. (A4A), and the Boeing Company (Boeing) signed a resolution formalizing their commitment to work together on the
“FARM to FLY” initiative. The FARM to FLY program will “accelerate the availability of a commercially viable and sustainable aviation biofuel industry in the United States, increase domestic energy security, establish regional supply chains, and support rural development.” Through this initiative, USDA has programs and funding available to advance feedstock development,” (masbi.org, 2013)

- “Commercial Aviation Alternative Fuels Initiative (CAAFI): The Commercial Aviation Alternative Fuels Initiative (CAAFI) seeks to enhance energy security and environmental sustainability for aviation through alternative jet fuels. CAAFI is a coalition that focuses the efforts of commercial aviation to engage the emerging alternative fuels industry. It enables its diverse participants – representing all the leading stakeholders in the field of aviation – to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels,” (masbi.org, 2013)

- “Defense Production Act Funding: The Department of Agriculture, Department of Navy, and the Department of Energy have committed to fund $510 million to assist the development and commercialization of a sustainable industry for aviation and marine biofuels, and to foster mutual cooperation among the federal agencies and across the public and private sectors,” (masbi.org, 2013).

MASBI published its first report and roadmap to success in early 2013. This report outlines their findings of current industry activities and biofuel research. With this report MASBI also published their “14 steps from available field to affordable fuel,” which suggests streamlining approval processes, building inter-industry support and policies, pursuing biofuel production improvement and tailoring agricultural products for jet fuel production.

Boeing
In conjunction and separate from MASBI, Boeing has also been focusing on pioneering environmental technologies for sustainable biofuels. Aside from conducting on ground, biofuel testing on their products, Boeing also heads many initiatives for renewable energy. “As a company, we are focused on sustainable biofuels produced from algae and other renewable resources that do not compete with food crops for land or water,” (Boeing, 2013).

According to Boeing’s Environmental Technologies division, Boeing is focusing to promote the development of sustainable biofuels. Boeing is also a founding member of the Sustainable Aviation Fuel Users Group (SAFUG), which is “devoted to reducing greenhouse gases emissions from commercial aviation,” (Boeing, 2013). Boeing also participates in the Commercial Aviation Alternative Fuels Initiative, which is a diverse industry coalition that addresses fuel alternatives in commercial, noncommercial and military aviation (Boeing, 2013).

In 2008, “Boeing and other industry collaborators conducted the first commercial aviation flight using a blend of biofuel mixed with traditional kerosene-based fuel. Subsequent demonstration flights have used a variety of sustainable biological sources, including jatropha, camelina and algae. All flights were conducted on Boeing airplanes with no modifications to the aircraft or engines,” (Boeing, 2013).

Boeing is working diligently on aviation biofuel processing technology and investing in feedstock research for biomass alternatives. Boeing has also worked closely with smaller bioenergy firms and universities to conduct research and testing of various feedstocks and biofuels.

There has been a lot of progress made for aviation within the commercial realm and industrial realm. Boeing also contributed to the creation of the “Beginner’s Guide to Aviation Biofuel,” which is an explanatory document about the research being conducted. In this guide it also covers flight profiles of tested biofuel flights.
SAFUG itself has enabled many of its members to pursue biofuel commitments to their fleets. A few to mention are: Air France achieving the world’s most CO2 efficient flight in 2011 using a HEFA aviation biofuel mixture and Qantas Airways operating Australia’s first commercial flight powered by sustainable aviation fuel. There has also been general aviation interest in biofuel.

**Aviation Alternatives**

Purdue University created a biofuel general aviation jet aircraft, which they flew to Oshkosh this year for a trial flight. Pilots flew the university’s Embraer Phenom 100 jet to the Experimental Aircraft Association AirVenture in Oshkosh on August 2, 2013. The one of the jet’s two twin Pratt & Whitney engines was filled with conventional jet aviation fuel, while the second engine was filled with biofuel blend prepared by the U.S. Air Force. The flight was in an effort to exhibit the potential for biofuel in general aviation.

Embry-Riddle Aeronautical University participates in the Green Flight Challenge, which challenges teams to create a “greener” flight using alternative means for fuel and energy. Green Flight is sponsored by NASA and offers the
largest prize for general aviation to the winner, $1.5 Million. Embry-Riddle’s Green Flight team created the Eco Eagle, which is a hybrid Stemme S10 motor-glider, modified to use an electric motor and bio-diesel engine. Using a biofuel created by the company Swift enterprises, Embry-Riddle tests and demonstrates the feasibility of biofuel in general aviation.

Another trend we are seeing in general aviation is the switch to diesel engines. Cessna Aircraft lends its size and reputation to the use of diesel technology with its 182 JT-A offering by Renault/SMA. Currently this engine is certified on the Cessna 182 and offers pilots the option to use diesel. In turn, it also allows for biodiesel to be used, creating a transition from conventional aviation fuel to biofuel. This is particularly attractive for flight academies pushing over 600 flight hours per aircraft that want to cut fuel expenditures.

Conclusion

Based on research, development and tested flights, it is proven that aviation could be biofuel powered on the basis that biofuel can create enough energy. However, it is the transition, both economically and physically, from conventional aviation fuel to biofuel that is the real feasibility issue. As the whole value chain of biofuel and aviation begin to make changes in policy, process and development, the transition will become easier and being to gravitate towards biofuel.

Like MASBI noted in their 2013 roadmap report, it takes a vested interest and cooperation from many broad-based industry members to make a change like this. Initially the cost will be cumbersome and very well may be more expensive than current fuel prices. General aviation aircraft with diesel or hybrid engines may in fact cost more than conventional ones. However, as time goes on and technology is developed, that cost will lessen.

As for current general aviation aircraft with conventional engines, that too has a solution. Redbird Simulations launched a new initiative to convert “Cessna Skyhawks to diesel power using Continental’s 135-hp Centurion 2.0. The project is called Redhawk and will be pitched to the training market as an alternative to
conventional avgas fueled trainers,” (Bertorelli, 2013). According to Cessna’s research, the diesel’s overall operating costs would be about 15 percent less than the equivalent gasoline engine after the change.

The transition to operating on biofuel is a feasible goal to set. Once the infrastructure of mass feedstock production, refineries, and distribution are realized, it will make the transition easier. Taking into account the desire to find an alternative and the resources available, it is possible to make the switch. However, that transition will not theoretically be realized for at least another 25 years. Though the push for finding an alternative is there, it will still take additional research, testing, and successes to make the jump to biofuel.
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