# *ALGAE – THE FUTURE OF JET FUEL*

By: Robert C. Hackney

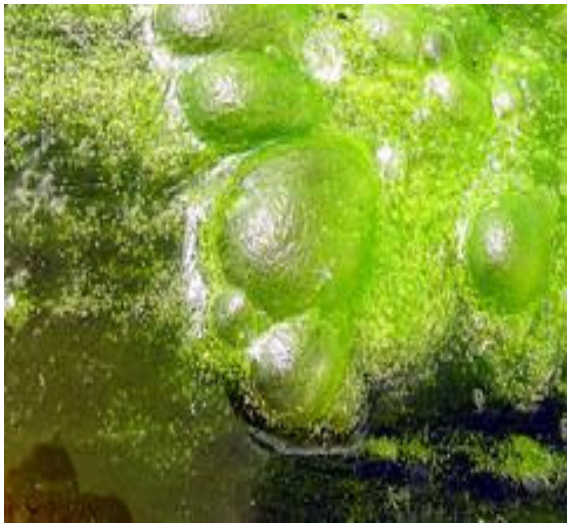
The aviation industry has been one of the first to attempt to embrace the development of an alternative algae-based fuel. While methods such as electricity and hydrogen are being touted as alternative fuel methods for automobiles, the jet engine is best suited to run on something that is closer to its original fuel, which is basically kerosene.

Scientists have known for some years that certain types of algae can produce an oil substance which is similar to crude oil. By now most people realize that crude oil is not the result of dead dinosaurs, but primiarly dead plant life. Up until recently, this was simply a novelty since crude oil was plentiful and cheap, and producing a substitute from algae was prohibitively expensive. It simply made no economic sense to try to develop algae as a fuel source until the price of crude oil started to rise dramatically. While the cost of producing fuel from algae is still more than the cost of jet fuel refined from petroleum, with the combination of economies of scale and rising petroleum costs, the concept is becoming potentially viable. This is similar to the situation with gold. Scientists know that they can extract gold from seawater. The cost of extracting the gold, however, is far in excess of the cost of searching for and mining gold out of the earth.

While algae based fuel has been produced in small quantities, there are not yet any facilities that are operating on a large scale. The issue of "scalability" has been one of the primary questons relating to the concept of algae based fuel production. The first large scale facility is scheduled to open in 2009, and will be watched closely to understand the potential viability of opening numerous facilities worldwide to produce algae for fuel.

The algae family is a big one, with more than 100,000 different species. We have all seen various types of algae, without really recognizing it as such. Fungus growing on rocks, grassy moss, kelp and pond scum are all forms of algae. Algae even comes in different colors like red, green and brown. Algae grows quickly and easily. All you need for natural growing algae is sunlight, water and carbon dioxide ($CO_2$). Through the process of photosynthisis, algae pulls $CO_2$ out of the air, and releases oxygen. Researchers are looking into locating algae growing facilities near $CO_2$ producing facilities which will help the algae grow and also help reduce $CO_2$ levels. This recylcing effect of $CO_2$ alone makes algae an exciting concept.

The basics of the algae as fuel concept involve an understanding of the three most important factors: 1) the type of algae; 2) the method of growing the algae; and 3) the oil extraction methodology.



## Types of algae

As we indicated above, there are over 100,000 different species of algae. The National Renewable Energy Laboratory ("NREL") has tested over 3,000 types of algae through its Acquatic Species Program. The conclusion of the NRELwas that algae had the ability to replace fossil fuels for both transportation and home heating. Researchers have been working on different strands and species to determine which types would be easiest to grow in abundance. Different species of algae contain different levels of oil, so the focus is on finding the right species that can be grown quickly, contain the highest level of oil, and be easiest for oil extraction.

## Growing Methods

*Open Pond*

Algae is frequently grown in the open pond method. The open pond method works best in warm areas with substantial sunlight. In many ways this is the easiest method, although there are negative features to this method. The biggest drawback is the potential for contamination from bacteria, competing forms of algae and the issue of having to inject $CO_2$. In addition, water temperature must be maintained at a constant level, which can be a challenge in an open pond. Bad weather and lack of sunlight can also have a negative effect upon the algae growth in an open pond.

*Closed Loop*

Many companies experimenting with algae use a closed loop system. A closed loop system uses clear plastic bags which promotes rapid growth since the algae get sunlight from two sides. A closed loop system frequently is built vertically, so that the plastic bags are stacked, which uses less horizontal area. Oil production is increased due to increased growth rate of the algae. By growing the algae in plastic bags the issue of contamination is also resolved.

*Closed Tank Bioreactor Systems*

Researchers are using closed tank systems, which are a variation on the concept of the open pond. Instead of outdoor ponds to grow algae, they use indoor systems of tank where temperature and light can be controlled. Bad weather and contaminants are eliminated, increasing the yield.

*Fermentation*

Experiments are being conducted using fermentation to increase production. By adding sugar to the process, the growth of algae increases. This process has a downside, and that is the amount of sugar required. Since one of the promotional benefits of algae is that we are not using food products for the creation of oil, the use of sugar eliminates that benefit.

## The Potential of Algae

While biofuels have been produced from corn, soybean, switchgrass, sugarcane and other cellulosic material, algae holds the greatest promise for the future. Algae can produce 30 to 100 times the oil yield of soybeans, and has no negative impact upon the consumable food market. According to Rice University researchers, the top three problems for humanity for the next 50 years, in order of importance, are energy, water and food. If we solve our energy problem by using our food, it moves food to the number one problem, which makes no sense. While industry analysts indicate that there is not enough arable land available to grow corn and other feedstocks to support our energy needs on a large scale basis, there is more than sufficient land for algae production. The United States Department of Energy estimates that algae fuel could replace all of the petroleum needs of the United States using land that is 1/7 of that used to grow corn harvested in the United States in 2000. In addition, that land does not need to be arable land, just available space.

## The Case for Algae-Based Jet Fuel

Jet biofuel research has exploded in recent years, and experimentation has taken place with products such as jatropha, soybeans, coconut oil, babassu oil, palm oil and other plant materials. For example, Air New Zealand recently flew a Boeing 747 on a two hour test flight to and from Auckland International Airport using a mixture of 50% biofuel made from jatropha and 50% standard jet A-1 fuel. Virgin Air's test flight of a 747 in February 2008 used a mixture of biofuel made from coconut and babassu oil.

Because of the issues discussed above relating to scalability and potential intrusion into food sources, the aviation industry has focused on the potential use of an algae-based jet fuel. One of the more promising projects is a joint venture between a Dutch algae company known as AlgaeLink N.V. and KLM Royal Dutch Airlines. AlgaeLink designs, builds, owns and operates algae growing facilities and biodiesel refineries on a world-wide basis.

Problem free jet biofuel is a difficult goal to attain. Jet fuel must meet challening standards, known as ASTM D-1655 specifications. These standards were developed by ASTM International (formerly the American Society for Testing and Materials), an organization that was formed over a century ago and is trusted world-wide as a source for technical standards for materials, products, systems and services. One of the common problems with biofuels is their tendency to freeze at high altitudes. A jet fuel substitute must have the same density, stability and flashpoint as standard A-1 jet fuel.

Solazyme, a biofuels company based in the San Francisco area, has recently announced that they have developed an algae-based aviation kerosene that meets the ASTM D-1655 standards. Solazyme's fuel was tested by Southwest Testing Institute and did not freeze at high altitude, which is common problem with bio-fuels. Solazyme's fuel is grown using a fermentation process using sugar to enhance growth.

A number of other companies are working on algae jet-fuel projects, including Sapphire Energy, based in San Diego, an extremely well funded start-up that has raised $100 million for “Green Crude Production.” Sapphire intends to produce gasoline, jet fuel and diesel. Continential Airlines, working in conjunction with Boeing and General Electric's aviation division, chose Sapphire to supply the bio-fuel for its aviation test of a Boeing 737 scheduled for the first quarter of 2009.

Also working with Boeing is Aquaflow Bionomic Corporation, a New Zealand based company. The focus of Aquaflow Bionomic is to complete research and development, and then

license its technology to third parties, thus staying out of the actual large scale manufacuring process. Another major company involved in developing the technology is Inventure Chemical Technology, based in Seattle. Inventure is not only working on jet fuel, and has entered into a partnership with Seambiotic, an algae producer, to build a biodiesel plant in Israel. Inventure will supply the algae to bio-fuel conversion process, and Seambiotic will supply the algae production technology. Inventure uses thermochemical processes and catalysts in a reactor system to turn algae into biofuel.

The Algal Biomass Organization is a nonprofit trade association formed in the State of Washington to promote the commercialization and marketing of biofuels. Aviation companies like Boeing, Virgin Atlantic, and Air New Zealand are corporate members of the organization, which reflects the importance of algae to the aviation industry. The Air Transport Association of America reports that fuel eats up about two-fifths of airlines' expenses. In addition, the International Governmental Panel on Climate Change reports that greenhouse-gas emissions from air travel are between 2 percent and 3 percent of world emissions.

As of the beginning of 2009 there are over 50 algae to biofuel startups. Which companies will survive and prosper will depend upon the economics of algae production and conversion. One thing seems inevitable, and that is that you will be flying in an algae fueled aircraft sometime in the future.

About the Author:

Robert C. Hackney practices law in Palm Beach County, Florida, and also serves as Executive Director of the Alternative Energy Association, a Florida not for profit corporation. He has lectured and authored a number of publications including *The Energy Revolution – 277 Things Every American Needs to Know About the New Energy Paradigm.* He also serves on the Advisory Board for the International Green Technology Center, and represents a number of companies active in the alternative energy industry. Information about the Alternative Energy Association can be found at www.alternativeenergyassn.com For comments on this article, Mr. Hackney can be reached at 561-776-8600.