Is Algae Fuel a Viable Alternative to Petroleum?

The Navy flew a jet with algal oil. Why can't I buy it at the pump?

by Jeff Sherin and Eric Norman

Gas prices as high as $4.60 per gallon have driven U.S. drivers mad, inspiring consumers to wonder if there might be an easy-to-use, economical alternative to fuel. In 2011, both a Navy F/A-18 fighter jet and a Continental Airlines Boeing 737-800 aircraft flew using biofuel made from algal oil mixed with standard jet fuel. Since algae is abundant, cheap and carbon neutral, could this be the answer to our fuel woes?

The History of Algae as a Fuel

Major investment in the conversion of algae to biofuels began in 1978 with the creation of the Aquatic Species Program. The main impetus for the program was a response to the oil shocks of the 1970s and the United States' subsequent push to reduce dependence on foreign oil. The program continued despite the decreasing price of oil in the early 1980s, but was canceled in 1996, largely based on the conclusion that algae production was too expensive in comparison with the cost of oil.

As the price of oil climbed in the early part of the 21st century, billions of dollars poured into private-sector algae companies. San Diego attracted a significant portion of this investment, leveraging its moderate climate and research base at UC San Diego to attract new companies such as Sapphire Energy and Synthetic Genomics, along with more established firms such as General Atomics.

But while the industry as a whole has continued to reduce costs and innovate, no company has yet achieved commercial-scale production of transportation fuel. There have, however, been some smaller successes, such as Solazyme's 2010 delivery of 20,000 gallons of algae-derived shipboard fuel to the U.S. Navy. What is not known, though, is the cost of the algal fuel. If algae is to compete, it must do so against the production cost of oil, which has a 100-year head start as far as technology and distribution are concerned.

Algae's Advantages

Deriving oil from algae has many advantages over other biofuels such as corn and sugar-based ethanol. For one thing, algae is not directly involved in our food chain. It also grows much faster, utilizes a higher percentage of the sun's energy than corn or

sugar (approximately 3 percent vs. 1 percent), can grow in wastewater and is capable of producing oil with a higher energy content than ethanol.

Research has focused on three main strategies to grow algae. The first two (raceway and photobioreactors) rely on photosynthesis, converting CO2 and sunlight to oil, while the third utilizes fermentation, which requires feedstock such as sugar cane.

Algae's Challenges

Each strategy involves complex processes of harvesting, extracting and refining the algae lipid into a deliverable fuel that can drop into a gas tank; and each option presents its own challenges and costs.

Based on a 2009 Seed Science study conducted for the British Columbia Innovation Council, the fermentation process produces the most economical fuel from algae at a cost of approximately $9 per gallon. Some companies have made claims of higher lipid content, which would drive the cost as low as $4 per gallon by creating twice as much oil from the same amount of algae. However, these yields have not been achieved at commercial scale.

One concern is that the growth rate of algae is inversely proportional to the amount of lipid production, which means that using a fast-growing strain has a low lipid content and vice versa. Being able to quickly grow algae with a high lipid content is an unsolved challenge. La Jolla's Synthetic Genomics is hoping to resolve this challenge by genetically engineering algae.

Genetic modification may also be useful in reducing the cost of extraction. Currently, the desired oil resides inside the algae and has to be removed, killing the algae. Researchers are trying to develop algae that "excrete" the oil, which would reduce the cost of drying the algae and extracting the oil.

However, genetically modified strains could present new complications in production. The European continent has been especially timid to purchase food products using these modified agricultural products, and their markets may not wholeheartedly accept algal products that have been genetically altered.

Other innovations are taking place in the area of cost cutting — co-locating with power plants that can provide inexpensive C02, for example. Solazyme is co-locating its fermentation plants with cheap feedstock providers such as sugar cane growers in Brazil.

However, the most significant detriment to the acceptance of algae as a fuel is the fact that gasoline is far less expensive.

The Low Cost of Gasoline

Although most consumers these days consider gasoline to be a considerable expense, Martin Sabarsky (Rady MBA '06), the CEO of algae company Cellana, pointed out that oil is "less expensive than bottled milk." In fact, in one San Diego neighborhood, Ralphs supermarket sells Alta Dena milk for $5.49 a gallon, while Chevron charges $4.25 for a gallon of regular unleaded. According to the U.S. Census, from 1984 to 2009 the average American household spent less on gas than on food, housing, home utilities, health care and entertainment.

The low cost of gas is what makes it difficult for algae to compete. And while many of us are used to thinking of the cost of petroleum as the price we see at the gas station, the true cost of production is much less expensive. What we pay at the pump includes taxes, plus additional costs for refining crude oil into petroleum and trucking it to the local gas station. According to the California Energy Commision, these costs are approximately one-quarter to one-third of the retail price. Oil made from algae also needs to be refined and transported. So to properly compare algal oil from a consumer standpoint, at the very least we need to add in these costs.

We should also remember that the market price of crude oil is highly volatile, which means that it can be relatively inexpensive at times. As recently as 2009, crude oil cost less than $1 per gallon. To compete with this fluctuation, companies producing fuel from algae would have to be able to survive these times as well, and not just spring into existence whenever oil hits $5 per gallon.

Higher-Value Algae Products

As it turns out, many algae companies have figured this out and are pivoting into higher-value product markets [**figure**]. Yossie Hollander, a successful entrepreneur who donated $5 million to Cornell to address the energy needs of developing countries, explained, "You can get more money per ton of fish food produced from algae than for a ton of oils for transportation." This article's authors can verify this, having been to the Sephora cosmetic chain to try Solazyme's skin-care line, which costs the equivalent of $10,000 a gallon!

The trend toward higher-value products will likely push the time scale back even further, as companies focus on developing algae strains that produce more protein and specialty oils such as Omega-3. Hollander continued: "The bottom line is this current trend will never lead to economically viable algae for oil replacement." Barring significant breakthroughs, it appears that algae-based fuel cannot achieve cost parity at any significant scale in the near future. The current production cost of oil is simply too low.

Thus, while the trillion-dollar fuel market may whet investors' appetites, companies such as Cellana are targeting higher-value products like Omega-3 oils and feedstock. In 2010, Dutch conglomerate DSM paid $1.09 billion to purchase Martek Biosciences, supplier of over 90 percent of the algae-derived Omega-3 oils in the United States.

Seeking the Fourth Generation of Algae Production

Taking into consideration the current market price for oil, algae cannot be viewed as a competitive threat at present, or even in the near future. However, oil carries with it many indirect costs. According to research from the Oak Ridge National Laboratory, loss due to gross domestic product (GDP) shocks and wealth transfer cost the U.S. an average of $684 billion per year over the last decade. Therefore, it is probably best that companies continue developing more cost-effective ways to harvest energy and other competitive fuels. Perhaps the model will evolve similar to that of the petroleum industry, where a barrel of oil is refined into high-value kerosene and low-value tar, with gasoline somewhere in the middle.

The best hope is for a fourth generation of algae production to be developed. Previous generations have dropped the price from $100 to $50 to $10. If the next generation drops the cost of production to $1 to $5 per gallon, it can be competitive, particularly if the costs of carbon and other indirect costs of oil are considered. Dr. Stephen Mayfield, director of the San Diego Center for Algae Biotechnology, looks toward existing mass agriculture as a model, suggesting that the next model is "going to be something that looks like a rice paddy."

Many look to the evolution in corn yields as inspiration for the potential of algae. In the 20th century, scientists were able to increase yields from 20 bushels per acre to nearly 140. Algae companies hope to use modern techniques to advance at a quicker pace. To achieve this goal, they should continue exploring innovative ways to reduce costs and achieve efficiencies of scale, while lobbying to have externalities such as carbon production included in the price of gasoline. In the meantime, expect to find more Omega-3 oils being produced directly from algae.