

Case Study: Algae-Based Biofuel Stocks

Abstract

- This case study examines the potential for algae-based fuel technologies to provide a new and advantageous way of manufacturing biofuels for transportation and to reduce greenhouse gas emissions from power plants. The results from research and development efforts and limited recent deployments of algae-based fuel technologies are encouraging, but the technology is still in its infancy and costs remain high. Several companies are now exploring options for producing algae-based biofuels and/or air pollution reduction systems.

Introduction

Algae-based technologies could provide a key tool for reducing greenhouse gas emissions from coal-fired power plants and other carbon intensive industrial processes. This case study examines the current state of this technology, how it might be implemented, and who the major players are in this emerging market.

Driven by escalating global climate change concerns and the rising cost of petroleum-based energy, companies are now starting to examine using certain forms of algae to reduce carbon emissions from power plants, generate renewable transportation fuels, and produce feed for fish and livestock.

The Basics of Algae-Based Fuel Production:

Photosynthetic organisms such as algae, plants and some photosynthetic bacteria use energy from the sun to combine water with carbon dioxide (CO₂) to create biomass. Microalgae are the most primitive form of plants, and are more efficient at storing solar energy than some higher plants because they have a simpler cellular structure.¹ According to the U.S. National Renewable Energy Laboratory (NREL), microalgae produce storage lipids in the form of triacylglycerols (TAGs) in a manner similar to higher plants. These lipids have many potential uses, one of which is to produce fatty acid methyl esters (FAMEs), which can be used to create biodiesel fuel that is an alternative to fossil-derived diesel fuel.²

From 1978 to 1996 the U.S. Department of Energy carried out a program known as the Aquatic Species Program (ASP) to develop renewable transportation fuels from algae. The ASP made significant progress in identifying algae that produce the most oil and can operate under specific environmental conditions. The ASP produced a collection of 300 mostly green algae and diatoms that are best suited to transportation fuels production, which is available to researchers and is housed at the University of Hawaii.³ Much of this case study is based on NREL's lengthy summary of the ASP program. NREL found that 7.5 billion gallons of biodiesel could be produced from algae on 200,000 hectares of desert land.

Potential Advantages:

¹ NREL

² Ibid.

³ Ibid.

Algae have several potentially significant advantages over other technologies to reduce greenhouse gas emissions from coal-fired power plants. They can provide a means to reduce carbon emissions by consuming waste gases through photosynthesis, rather than through carbon sequestration technologies. They can also be used to manufacture biodiesel fuels for use in vehicles by producing oils that can be used for manufacturing biodiesel. Microalgae are efficient producers of oils, and can produce 30 times the amount of oil per unit area of land compared to terrestrial oilseed plant varieties.⁴

Biodiesel Production:

Algae have certain qualities that make the organism an attractive option for biodiesel production. Unlike corn-based biodiesel which competes with food crops for land resources, algae-based production methods, such as algae ponds or photobioreactors, would “complement, rather than compete” with other biomass-based fuels.⁵ The growth requirements for microalgae are simple: they need water and CO₂. Therefore, unlike corn or other biodiesel crops, algae do not require significant inputs of carbon intensive fertilizers. Some algae species can even grow in waters that contain a large amount of salt, which means that algae-based fuel production need not place a large burden on freshwater supplies.⁶ Because of algae’s versatility and efficiency, NREL researchers found that resource limitations are not an inhibiting factor on algae-based technology.

Carbon Consumption:

On the carbon reduction side, for the past thirty years or more researchers have focused on algae’s potential to essentially eat up much of the carbon dioxide emitted by coal-fired power plants and use it to create lower carbon transportation fuels in the form of biodiesel. The summary report for NREL’s algae research effort stated, “It is a technology that marries the potential need for carbon disposal in the electric utility industry with the need for clean-burning alternatives to petroleum in the transportation sector.”⁷

One approach to using algae to reduce power plant emissions consists of constructing an algae pond, or “farm.” Carbon emissions would be pumped into the water, and natural oils would then be extracted from it. According to NREL, the typical coal-fired power plant emits flue gas containing up to 13 percent CO₂. This gas can be used to fertilize algae ponds. NREL researchers investigated this approach and found that it “provides an elegant approach to recycling of the CO₂ from coal combustion into a useable liquid fuel.”⁸ The governments of Japan, France and Germany, in addition to private firms, have also pursued the development of closed bioreactor designs for algae production.⁹

In addition to manufacturing biofuels for transportation and reducing carbon emissions from coal-burning power plants, there is also some interest in utilizing algae to produce

⁴ Ibid.

⁵ Ibid.

⁶ Ibid.

⁷ Ibid.

⁸ Ibid.

⁹ Ibid.

hydrogen-based fuels. Algae produce hydrogen as part of photosynthesis, and it may be possible to genetically manipulate algae and to alter algae's surrounding environment to optimize hydrogen production.¹⁰

Emerging Players:

According to NREL, the small size of the scientific community working on algae-based fuels has inhibited the development and deployment of this technology. "The study of microalgae represents an area of high risk and high gains," NREL stated.

Despite the economic risks involved, presently there are several companies in the United States that are exploring ways to use algae to reduce greenhouse gas emissions from power plants and to generate biodiesel. These companies, which include GreenFuel, Solazyme, and LiveFuels, have picked up where U.S. federal government research efforts left off in 1996.

Solazyme, a San Francisco based startup, has developed a new process for making fuel from algae that utilizes sugar as the main feed and grows genetically modified algae in dark containers. Solazyme claims that keeping algae in the dark and thereby turning off photosynthetic processes actually boosts oil production by activating other metabolic processes that can help convert sugar into oil. In addition, feeding algae sugar may enable algae to grow in higher concentrations than the sunlight-based methods of algae ponds.¹¹

Another player in the American algae-based fuels market is GreenFuel Technologies of Cambridge, Mass. GreenFuel has conducted a trial run at the Massachusetts Institute of Technology's (MIT) Cogeneration power plant that showed its algae system can reduce carbon dioxide emissions by up to 82 percent, as well as cut 85 percent of the nitrous oxide emissions.¹²

GreenFuel has been negotiating beta installations cross the U.S. and internationally. The company claims it "harnesses photosynthesis mechanisms to simultaneously provide both cost-effective air pollution control and high quality biomass production." The company says that its systems don't require power plants to modify their internal systems and don't require fertile land or potable water.¹³

GreenFuel recently won an energy emissions award for its demonstration project at an Arizona utility that marked the first time that smokestack gases were used to grow algal biomass for conversion into biofuels. However, it has also run into some financing and management issues as it tries to move towards commercially viable projects.¹⁴

LiveFuels is a California-based company that is partnering with federal research institutions and other entities to develop and deploy algae-based biofuel systems. The company is focusing its attention away from photobioreactors and genetic modification. "... the fact of

¹⁰ *Technology Review*.

¹¹ *Technology Review*.

¹² GreenFuel web site.

¹³ *Ibid*.

¹⁴ *Ibid*, news reports.

the matter is, the capital expenditures of photobioreactors will simply kill a company," LiveFuels CEO Lissa Morgenthaler-Jones told cleantech.com.¹⁵

Outside of the United States, Aquaflow Bionomic Corporation (ABC) of New Zealand is pursuing a different approach to algae-based biofuels. It is seeking to harvest algae from effluent system settling ponds and other waters that are rich in nutrients, rather than via bioreactors or by engineering high lipid yield algae. Aquaflow Bionomic believes its approach is less costly than the other methods, and that it could accomplish the dual goals of producing biofuels and cleaning contaminated water from industrial activities.¹⁶

Another company that is pursuing algae-based fuels is Algae BioFuels Inc., a wholly-owned subsidiary of PetroSun, Inc. The company's R&D and production facilities are in the United States and Australia. PetroSun recently announced that its first commercial algae-to-biofuels farm, located near Harlingen, Texas, would begin operations this spring. It consists of a 1,100-acre salt-water open pond system, and will use the algal oil produced from this operation for algae-to-jet fuel and algae-to-bioplastics R&D projects.¹⁷

Challenges:

The challenges facing developers of algal biofuels and pollution reduction systems are similar to those of companies trying to scale up other renewables. In addition to the technological hurdles, perhaps the biggest obstacle standing in the way of deploying algal fuel production facilities is the high cost of these fuels compared to more conventional biofuels.

NREL concluded that the open pond designs would be the most economical choice for the foreseeable future, and that biological factors would exert the biggest influence on determining the cost of algal technologies. For such technologies to be viable, algae would need to produce oils at the highest levels of conversion possible, and even then the cost of producing biodiesel from algae might be two times higher than petroleum diesel costs, NREL stated.¹⁸ Although costs remain a barrier to algae fuels production, the economics have become more favorable to such efforts since the NREL study was completed.

Much of the work on algae today is being conducted using proprietary photobioreactors due to problems that are unique to algae farms, such as temperature fluctuations. However, photobioreactors typically have a higher cost than open algae ponds. A biofuels research group at the University of New Hampshire stated that bringing algal biodiesel to market depends on developing photobioreactors that can result in higher yields at significantly reduced costs from current levels.¹⁹

Another inhibiting factor is the lack of government R&D investments in algal fuel technologies. Some major industrialized countries have invested significant sums in research and development resources to develop algae-based fuel systems, notably Japan and

¹⁵ Cleantech.com article.

¹⁶ Aquaflow Bionomic web site.

¹⁷ Green Car Congress, Marketwire News Release.

¹⁸ NREL.

¹⁹ University of New Hampshire Biodiesel Group.

Germany. The United States has lacked a federal research effort for the past ten years, which may be an inhibiting factor for American companies. This is changing though, since NREL recently signed an agreement with the oil company Chevron to conduct further research on algae-derived biofuels.²⁰ According to the *New York Times*, the Pentagon is also financing research into producing jet fuel from algae.²¹

Other challenges include obtaining private sector funding for research and development, proving the cost-effectiveness of the algae-based technologies, and negotiating partnerships with power plant owners to test and deploy algal systems.

Sources:

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²⁰ *New York Times*.

²¹ *Ibid*.