CASE STUDY:
GREENFUEL TECHNOLOGIES CORPORATION

Introduction

GreenFuel Technologies is a company that researches and develops algae-based clean energy technologies. Founded in 2001 in Cambridge, Massachusetts, the company is among the leading innovators of algae-based technologies that seek to harness the ability of algae to manufacture lipids for biodiesel fuel, among other purposes. The company couples algae systems with conventional fossil fuel power plants or other carbon dioxide sources in an effort to create a technological system that will reduce carbon dioxide emissions while also manufacturing compounds for biodiesel fuel and livestock feed.

Theme

As an early entrant into the increasingly competitive algae-fuels market, GreenFuel has a longer track record than its competitors, and its experience may put it in a better position to capitalize on such technologies once it has proven to be more cost effective.

The potential for algae to be used to reduce greenhouse gas emissions and create less carbon intensive automobile fuels has been well known for several decades, but it is only recently that more companies have begun to invest more in research and development funds into this area.

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. However, despite the large potential for algae technologies to make great gains in solving global climate change and world energy challenges, such systems are certainly no panacea, and to date the technology remains somewhat unproven. GreenFuel has encountered significant roadblocks in its efforts to bring algae-based fuels to market, and make a profit while doing so. Its experiences offer a valuable lesson for other entrants into the algae market and other emerging forms of renewable energy.

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 (CO_2) 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 triagcyglycerols (TAGs) in a manner similar to higher plants. These lipids have many potential uses, one of which is to produce fatty

[1] NREL

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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. Some federal algae research efforts have recently resumed as a result of public-private partnerships.

Algae have several potentially significant advantages over other technologies to reduce greenhouse gas emissions from coal-fired power plants, such as carbon sequestration and biodiesel production methods manufacturing corn-based ethanol.

Biodiesel Production:

Microalgae are efficient producers of oils, and can produce 30 times the amount of fuel per unit area of land compared to either oilseed plants or ethanol-producing crops.[3]

Unlike corn-based ethanol, which competes with food crops for land resources, algae-based production methods would "complement, rather than compete" with other biomass-based fuels.[4] The growth requirements for microalgae are simple: they need water, CO_2, and sunlight. Algae do not require significant inputs of carbon intensive fertilizers or other agricultural supports. 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.[5]

In addition to its uses for biodiesel, algae may also be used to produce high protein livestock feed.

Carbon Emissions Reductions:

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 to create 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."[6]

There are several approaches that can be taken to growing algae to reduce power plant emissions and manufacture oils for biodiesel. One method is through open algae ponds.

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[2] NREL
[3] NREL
[4] NREL
[5] NREL
[6] NREL

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Using this method, gas containing carbon dioxide would be pumped into the water, promoting algae growth. GreenFuel, however, believes that algae ponds are not the most promising approach. It has focused its research and development on creating productive and economically viable closed photobioreactors that would harness the capabilities of certain types of algae to produce large amounts of oil under certain controlled conditions. GreenFuel has found that algae farms are too vulnerable to natural environmental variations, such as swings in temperature, to be reliable producers of large amounts of oil.[7] Critics of photobioreactors say they are too expensive.

Economic Factors:

A biofuels group at the University of New Hampshire has stated that bringing algal biodiesel to market depends on developing photobioreactors that can result in higher yields at significantly reduced costs from current levels.[8]

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 algae-based 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.[9] However, since that report was produced, the economics of using algae to produce biodiesel and reduce carbon emissions have become more favorable overall, increasing the incentives for companies like GreenFuel to invest in photobioreactor designs.

History and Internal Factors

GreenFuel was formed in 2001 by an Israeli chemical engineer, Dr. Isaac Berzin, and others to translate promising laboratory research on algae fuels into a profitable enterprise dedicated to the production of the next generation of clean fuels. At the time, Berzin was a researcher at MIT. Since its inception, GreenFuel has maintained close relations with the school, even testing its technologies at a university-run power plant.

Berzin, who now serves on GreenFuel's Scientific Advisory Board, originally pursued algae research for an experiment he conducted with Payload Systems, a company that develops equipment for NASA astronauts.[10]

GreenFuel is currently led by interim CEO Bob Metcalfe, who replaced Cary Bullock as CEO in 2007 (Bullock now serves as vice president of business development). Metcalfe is known for the breakthroughs he achieved in computer networking technology while serving as the leader of 3COM, the telecommunications company he founded. He is currently a partner with GreenFuel investor Polaris Venture Partners, and took the reins

[7] Popular Mechanics
[8] UNH
[9] NREL
[10] Christian Science Monitor, Boston Globe

of the company during a period of financial difficulty for the firm after a series of setbacks for some of its technologies in 2007. At that time, GreenFuel was forced to lay off half of its 50-person workforce, but since then GreenFuel has secured additional venture capital financing and is rumored to be close to a deal potentially worth up to $92 million to manufacture an algae fuel facility in Europe.[11]

According to the GreenFuel web site, the company's current major sources of venture capital are Access Private Equity, Draper Fisher Jurvetson, and Polaris Venture Partners.[12]

Advantages:

GreenFuel is in a good competitive position relative to more recent entrants into the algae fuel marketplace because of its longer record of experience in researching and developing bioreactor systems. Some other companies, such as Royal Dutch Shell, are focusing their efforts on algae ponds to reduce power plant carbon dioxide and nitrous oxide emissions and to manufacture oils for biodiesel production.[13] However, although this technology may be cheaper than GreenFuel's photobioreactors, some experts believe they will not be as productive. In addition, GreenFuel benefits from its relationship with MIT by staying involved with cutting edge scientific research on clean energy technologies.

Regarding its technology, GreenFuel's closed-bioreactor system reportedly can be used to manufacture biodiesel, ethanol, or methane, depending on demand. Jack Lewnard, then VP of Process Development at GreenFuel, told Wired magazine, "The front-end algae production facility is the same in each case," with the difference being the species of algae chosen for the task.[14]

Since 2004, GreenFuel has conducted trials of its technology through partnerships with different power plant operators. For example, the company has been testing its technology at two facilities owned by the Arizona Public Service Company, as well as the Sunflower Integrated Bioenergy Center in Holcomb, Kansas.

GreenFuel has also been conducting tests at a coal-based power plant in neighboring New Mexico. "The results provide evidence of the financial viability of using the emissions of a power plant to grow algae for the exclusive purpose of creating biofuels," GreenFuel said in a press release.[15]

The Redhawk facility project in Arizona earned APS and GreenFuel the Emissions Energy Project of the Year Award from Platts in 2006. That partnership, according to then-GreenFuel CEO Cary Bullock, marked the first time that algae biomass created on site via connection to a commercial power plant was converted to both transportation-

[11] XConomy story
[12] GreenFuel Web Site.
[13] Business Week
[14] Wired
[15] GreenFuel Press Release

grade biodiesel and ethanol. He said the process used at the Redhawk facility can absorb up to 80 percent of carbon dioxide emissions during the day from a natural gas fired power plant.

"Unlike typical agricultural biofuel feedstocks such as soybeans or corn which have a limited harvest window, algae multiply every hour can be harvested every day," Bullock said.[16]

Last year GreenFuel began testing an algae-based system at NRG Energy Inc.'s Big Cajun II 1,489 megawatt coal-fueled power plant in New Roads, Louisiana. GreenFuel claims that if fully operational, the system could potentially provide up to 8,000 gallons of biodiesel per acre annually under ideal conditions.

Power plant operators such as NRG Energy have been motivated in large part by the potential for GreenFuel's technologies to provide a means to reduce carbon emissions from energy production without requiring significant retrofitting of existing power plants. This compares favorably against the likelihood that other carbon sequestration technologies will require expensive facility alterations.

Globally, GreenFuel maintains a partnership with IGV, a private German industrial research institute headquartered in Pottsdam. Under the terms of their agreement, the two entities share algae bioreactor technology and work to pursue commercial opportunities in Europe.[17] GreenFuel has also licensed its technology to a company in Australia.[18]

Disadvantages:

GreenFuel has encountered significant impediments on the road to scaling up its technologies, mainly due to the high costs of experiencing technical setbacks.

As previously stated, the company went through its biggest period of turmoil in 2007, when it was forced to reorganize its leadership and devise new near-term plans. Part of the problem for GreenFuel arose during testing of the company's third generation of its algae system at the Redhawk natural gas power plant in Arizona, where algae production exceeded expectations and overwhelmed the capacity to process it. This precipitated a shutdown of the testing program for a time, in what interim CEO Metcalfe called a "success failure."[19]

"The Arizona greenhouse shutdown was a "success failure" of a kind that often interrupts the commercialization of emerging technologies," Metcalfe wrote in a letter that later appeared in press accounts. "Our current third-generation engineering scale greenhouse grew algae faster than expected, demonstrating again that CO2 recycling and algae

[16] GreenFuel Press Release
[17] Business Wire
[18] Mass High Tech
[19] Xconomy story

productivity can be achieved at scale in our high-technology greenhouses. However, this very success triggered failure, as we could not harvest the rapidly growing algae quickly enough. Their unexpected density limited light and nutrient supply, which caused them to start dying. As a result, the greenhouse had to be shut down."

In addition to the Arizona shutdown, GreenFuel also received bad news in the summer of 2007 from outside experts who found that the company's latest algae-harvesting system would prove to be more than twice as expensive as the company's targets. "We've decided that the best course is to continue driving toward lower costs, higher returns, and larger markets. The best course is to accelerate scaling of our fourth-generation greenhouse technology," Metcalfe stated in response.

The company brought in Metcalfe to see it through the turbulent waters, and also laid out an ambitious near-term agenda to get back on track. The agenda included:

- Cutting expenses.
- Raising cash from investors.
- Restarting the demonstration project in Arizona.
- Accelerating the scale up of the company's fourth-generation algae greenhouse technology.
- Developing a project plan for a commercial scale algae greenhouse and signing by November at least one letter of intent with a partner.
- Recruiting a new CEO.
- Closing a new round of equity financing.[20]

Remarkably, the company has met most of these goals, although it has not yet found a permanent new CEO.

Conclusion

GreenFuel has successfully brought itself back from the brink of closure in 2007 by changing its leadership, securing additional venture capital, continuing to conduct demonstration projects, and reportedly signing a new major deal to build a plant overseas. However, it now faces an even more crowded marketplace of companies eager to cash in on the potential benefits of developing scalable algae-based biofuel and carbon capture systems. Since GreenFuel's inception in 2001, there have been several major new entrants into the algae fuel marketplace, including companies such as Royal Dutch Shell, Solazyme, PetroSun Inc., and LiveFuels.

[20] XConomy, Mass High Tech

Sources

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