PROJECT facts
U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Sequestration

03/2006

Recovery and Sequestration of CO_2 From Stationary Combustion Systems By Photosynthesis of Microalgae

Background

Most anthropogenic carbon dioxide (CO_2) emissions result from the combustion of fossil fuels for energy production. Photosynthesis has long been recognized as a means, at least in theory, to sequester anthropogenic CO_2. Aquatic microalgae have been identified as fast growing species whose carbon fixing rates are higher than those of land-based plants by one order of magnitude. A large-scale photo bioreactor would be similar to a large display of solar panels, except instead of producing electricity, the solar energy would serve through photosynthesis by microalgae to convert CO_2 from fossil fuel combustion to stable carbon compounds for sequestration. Some high-value products would also be produced to offset the carbon sequestration cost. An ideal methodology for photosynthetic sequestration of anthropogenic carbon dioxide has the following characteristics: (1) a high rate of CO_2 uptake and mineralization of CO_2, (2) resulting in permanently sequestered carbon, (3) produce revenue from sale of high value products, and (4) use of concentrated, anthropogenic CO_2 before it enters the atmosphere. In this research program, Physical Sciences Inc. (PSI), Aquasearch, and the Hawaii Natural Energy Institute at the University of Hawaii jointly developed technology for the recovery and sequestration of CO_2 from stationary combustion systems by photosynthesis of microalgae. The research was aimed primarily at quantifying the efficacy of microalgae-based carbon sequestration at an industrial scale. The principal research activities were focused on demonstrating the ability of selected species of microalgae to effectively fix carbon from typical power plant exhaust gases. The results were used to evaluate the technical efficacy and associated economic performance of large-scale photobioreactor carbon sequestration facilities.

Primary Project Goal

The primary project goal was to develop technologies pertaining to: (1) treatment of effluent gases from fossil fuel combustion systems; (2) transferring CO_2 into aquatic media; and (3) converting CO_2 efficiently by photosynthetic reactions to materials to be reused or sequestered.

Objectives

- Determine the effect of process variables on the production of various strains of microalgae
- Optimize and demonstrate an industrial-scale photobioreactor
- Perform economic analyses of commercial-scale microalgal CO_2 sequestration technology

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COST

Total Project Value
$2,361,111

DOE/Non-DOE Share
$1,682,028 / $679,083

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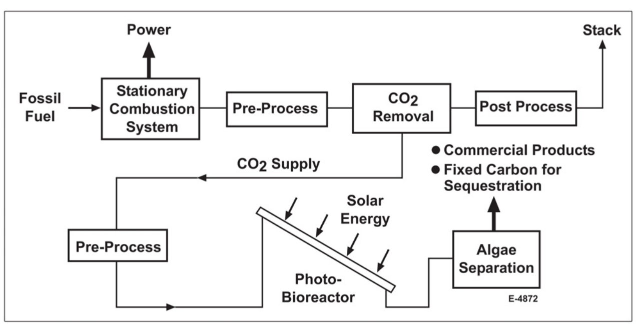
Accomplishments

- Analyzed up to 50 strains of microalgae for high value pigments, productivity, and CO_2 sequestration potential.
- Completed scale up of six microalgal strains at full commercial scale outdoor photobioreactors (0.41 m diameter, up to 25,000 liter capacity).
- Completed experimental work on biomass separation (harvesting) for five microalgal strains grown in pilot and full scale outdoor photobioreactors.
- Modeled the costs associated with biomass harvested from different microalgal strains.
- Completed design of key components including: CO_2 removal process; CO_2 injection device; photobioreactor; product algae separation process; and process control devices.
- Developed a photobioreactor design concept for biofixation of CO_2 and photovoltaic power generation.
- Conducted economic analysis for photobioreactor carbon fixation process.
- Developed an economic model to be used in predictions of carbon sequestration cost for a number of scenarios.

Benefits

This project represented a radical departure from the large body of science and engineering in the area of gas separation. This research has shown significant potential to create scientific and engineering breakthroughs for the operation of controlled, high-throughput, photosynthetic carbon sequestration systems. This type of system will reduce carbon dioxide emissions generated by fossil fueled powerplants. The microalgae used and grown in this process can produce high-value pharmaceuticals, fine chemicals, and commodities. Revenues from the sale of these products can help offset carbon sequestration costs.

Conclusion: microalgal-based carbon sequestration technologies can, in principle, not only cover the cost of carbon capture and sequestration but also produce a profit. The technology's cost effectiveness will be dependent on the production of high value product(s) and its markets.



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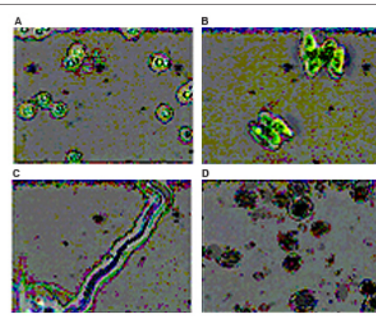

Microphotographs of four types of algal cells at a magnification of 400x showing differences in size and morphology