PROJECT facts

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

Sequestration

03/2006

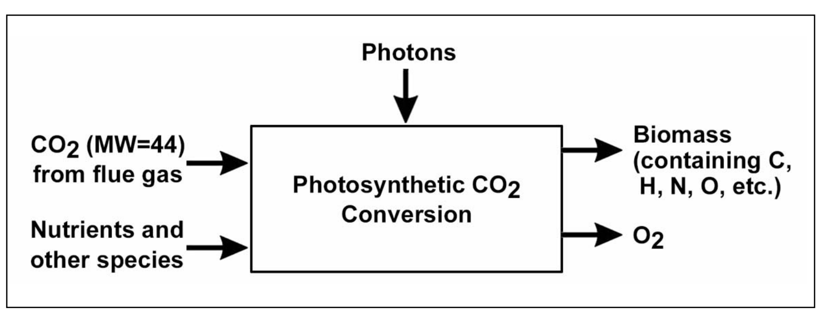
Enhanced Practical Photosynthetic CO_2 Mitigation

Background

Biological carbon sequestration, in particular, engineered photosynthesis systems, offers advantages as a viable near-to-intermediate term solution for reduced carbon emissions in the energy sector. Photosynthetic (or “natural” sequestration) systems produce usable by-products (biomass). Further, such systems could minimize capital and operating costs, complexity, and energy required to transport CO_2 that challenge sequestration in deep aquifers or mines. Lower capital costs are extremely important, especially to small generators, who may not be able to afford separation and CO_2 delivery systems that are only cost effective if done on very large scales. For coal to remain competitive, especially in the rapidly emerging distributed generation market (< 50 MW), and to ensure future fuel diversification, a portfolio of viable and practical sequestration techniques will have to be developed. Photosynthetic systems should be a part of that portfolio. The concept behind engineered photosynthesis systems is straightforward. Even though CO_2 is a fairly stable molecule, it is the basis for the formation of complex sugars by green plants through photosynthesis. The relatively high content of CO_2 in flue gas (approximately 14% compared to 350 ppm in ambient air) has been shown to significantly increase growth rates of certain species of microalgae. Therefore, application is ideal for contained systems, engineered to use specially selected strains of microalgae to maximize CO_2 conversion to biomass, absorbing greenhouse gases. In this case, the microalgal biomass represents a natural sink for carbon.

Primary Project Goal

The main purpose of this research was to demonstrate and optimize low-risk methods of CO_2 mitigation based on existing biological organisms capable of significant CO_2 uptake and offer a valid near-term solution for the CO_2 sequestration problem.



Simple diagram of the photosynthetic conversion process of CO_2 to biomass and oxygen

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COST

Total Project Value
$1,369,495

DOE/Non-DOE Share
$1,075,022 / $294,473

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Objectives

The project demonstrated the technical and economic feasibility of using an "optimized" enhanced photosynthesis system that (a) separates and uses various spectral regions of direct, non-diffuse sunlight to maximize cyanobacteria growth, (b) directly decreases CO_2 concentrations in the emissions of fossil generation units, (c) reduces the required space needed to mitigate CO_2 emissions (compared to other biological techniques) by an approximate factor of 25, and (d) simultaneously produces enough electrical energy to nearly self-power the entire sequestration system.

Accomplishments

- Isolated 15 unialgal cultures for biological sequestration suitable for deployment in flue gases at adiabatic saturation temperature
- Performed several long-term "continuous" runs of the solar-powered bioreactor where the cyanobacteria attached, grew, and were harvested (in repeated cycles)
- Measured productivity of cyanobacterial growth was shown to depend on light level (not saturated in the bioreactor due to careful lighting design), with the average productivity being approximately 50 g/m^2/day in "typical" Ohio sun
- Life-cycle economics of entire bioreactor design were analyzed, with the key factor being the need to reduce the cost of the solar collector and light delivery system
- Extrapolation of productivity testing data indicates that approximately 0.7 acres of bioreactor footprint is needed to remove 55% of CO_2 emitted (time-averaged throughout the day) per 1 MW of coal-fired power generation.
- Licensed the patent "Enhanced Practical Photosynthetic CO_2 Mitigation" (#6,667,171)

Benefits

Three major benefits, in addition to CO_2 mitigation, could result from the use of this novel method of photosynthetic sequestration. The production of oxygen would be one benefit. Oxygen is a natural product of photosynthesis. The second benefit of this project would be the reduction of gaseous pollutants including potential NH_3 slip (from selective catalytic reduction to control NO_X) and NO_X. In terms of other pollution control, this process could provide NO_X control at no additional cost. First, the flow process used to enhance soluble carbon concentration is a natural scrubber. Not only is NO_X converted to nitrates, SO_X is converted to sulfates and sulfites, and any NH_3 that might slip through an upstream SCR process for NO_X reduction will be scrubbed as well. Both NO_X and NH_3 scrubbing are not only an additional benefit; such scrubbing is beneficial to photosynthesis, as the microalgae require nitrogen to grow. The third benefit would be from the production of biomass with beneficial end-uses. The resulting biomass has numerous beneficial uses. In addition to being a potential fuel, microalgae have been used as soil stabilizers, fertilizers, in the generation of biofuels, such as biodiesel and ethanol, and to produce H_2 for fuel cells. In recent tests, it also has shown suitable ignition characteristics to be co-fired with coal in pulverized coal-fired generation units.