Biofixation of CO_2 emissions from Natural Gas Fired Power Generation using Microalgae

Carbon Capture Corporation is a privately held company dedicated to the reduction of carbon dioxide (CO_2) emissions from electric power plants. Founded in 2006, the company is located in Southern California where it owns and operates a 326-acre research center and a 160-acre site for a proposed 46-megawatt ultra-low emission power generation facility. Carbon Capture's process development team currently comprises twenty individuals with expertise ranging from aquaculture, biotech and biology to power generation, real estate development and engineering.

Facility and Project Description

Carbon Capture has applied its initial financial and team resources to acquisition of research and demonstration facilities and to development of a prototype power plant applicable to natural gas fired power generation, California's primary source of power. The research facility in Imperial Valley is optimally positioned for commercial scale development, demonstration and refinement of Carbon Capture's biofixation emissions control approach for CO_2:

- Commercial open ponds and additional acreage for large scale demonstration
- Optimal climate conditions for open pond algae production, ample sunlight
- Beneficial use of available water resources
- Very low permeability soil for cost effective pond operation
- Assembly of a commercial power generation facility, the source of CO_2.

Anticipated benefits from successful CO_2 biofixation on a commercial scale include:

- Ultra low emission power generation achieved in a short time frame and at a relatively low cost. Initial results indicate potential to substantially exceed Assembly Bill 32 emission reduction goals.
- Climate Action Registry registration for natural gas fired power generation
- Generation of an additional agricultural industry on impaired/degraded agricultural land in an economically disadvantaged area.

Technical Strategy – Capturing Power Plant Emissions with Algae

Algae: Spirulina platensis has been selected for the following features:

- robustness
- ability to withstand high pH – high alkalinity requirements of the culture media
- high pH environment inhibits growth of competitive species
- larger size facilitates greater ease/lower cost of harvesting
- high protein content offers diverse applications, including fish meal substitution in marine aquaculture diets
- proven success in commercial open pond production

Mass Transfer of CO_2

The initial phase of the Carbon Capture approach is to remove CO_2 from the efflux gas from combustion of fossil fuels and to store that emitted CO_2 in the form of carbonates in the pond culture solution of Spirulina microalgae. The algae convert solar energy to potential chemical energy and biomass by fixation of the carbonate through photosynthesis. Because CO_2 contained in the power plant emissions is converted into carbonate prior to the biofixation process, time averaging of the CO_2 emissions fluctuations is accomplished to support partial load operation as discussed below.

When algae are provided unlimited nitrogen, phosphorus, and potassium for maximum growth with available sun light, CO_2 is extracted from the water phase faster than the CO_2 can transfer from the air to the water. This rapid extraction causes the pH of the pond water to increase as the equilibrium difference in CO_2 partial pressures between the liquid and the air increases. At pond pH exceeding 10.5, the shortage of CO_2 starts to limit algae growth rates (no longer limited by light, but limited by lack of CO_2).

With exposure of this high pH carbonate buffer system to the flue gas, CO_2 is removed from the flue gas and the pH of the culture water decreases to more reasonable levels (in the mid pH 8 range with the present concepts). This lower pH culture water is then returned to the ponds and blended with the high pH water of the ponds. Present estimates project a 0.3 pH change from a day without the power plant CO_2 supply or a day without sunlight. This allows the system to "buffer" normal operational variations associated with natural gas power generation.

When culture water is equilibrated with air (i.e. an air stone in a beaker), the pH of the water comes to an equilibrium level with the air (the exact value depends upon component solutes and their physico-chemical properties). As long as Carbon Capture operates the ponds with a pH level above that equilibrium level, 100% of the CO_2 removed from the flue gas will be absorbed by algae growth and the algae will additionally remove some CO_2 from the atmosphere. If the pH goes below this equilibrium value, some of the captured CO_2 will go into the atmosphere as the pond water moves towards equilibrium with the atmosphere. As long as the average pH remains near equilibrium, 100% effective utilization of the carbonate (which represents a certain fraction of the CO_2 from the flue gas) can be achieved.

Projected Magnitude of CO_2 reduction for a 47 Megawatt (MW) Power Plant

Carbon Capture's proposed 47 MW peaker power plant is projected to generate one million pounds per hour of emissions from its stack, of which about 5.5% would be CO_2. This is equivalent to a CO_2 production of 25 tons per hour. If the plant was running every hour of every day during any given year, the total yearly production of CO_2 would be 25 tons x 24 hours x 365 days = 219,000 tons per year. Because projects do not operate continuously, annual CO_2 production will be adjusted in accordance with the actual capacity factor. For example, assuming a 10% capacity factor and a 50% capture efficiency, CO_2 reduction from this facility could be 10% x 50% x 219,000 = 10,950 tons per year.

> *What is the impact?*
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> For illustration purposes, 219,000 tons per year of CO_2 emissions may be equivalent to such emissions from 68,438 cars.[1] Under this scenario, the reduction of 10,950 tons of CO_2 from this 47 MW power plant corresponds to the removal of 3,422 cars from circulation.

[1] Assumes 200 g/km CO_2 emission and 16,000 km per year
(source: http://www.newcarnet.co.uk/co2_car_emissions.html)

Applicability to existing power plants in California?
This technology has the potential to apply to power generation from natural gas (41.5% of California supply), coal (15.7%) and even certain renewables (10.9%) such as geothermal and biomass for instance, thereby offering a potential improvement on nearly two thirds of the total power generation in California.[2]

Other Applications
Carbon Capture's algae based carbon absorption process is currently designed to facilitate ultra low emission power generation from natural gas. The focus of future research will be on transferring this proven technology to coal and biofuels applications, as well as other industrial uses.

Estimated Procurement and Operating Costs
Carbon capture anticipates a cost of $20 per ton of CO_2 reduced. Additional research is required to confirm this initial expectation.

Potential Roadblocks to Development and Deployment
The proposed process requires: i) favorable sun exposure, ii) a relatively large foot print for the production of algae and iii) access to water. We believe that California, because of its commitment to reducing green house gases combined with its sunny conditions, is an ideal candidate for the development and implementation of Carbon Capture proposed technology. The expansion to other states is likely to follow primarily in the southern part of the country. Research efforts at Carbon Capture are directly addressing approaches to expand the technology to less sun exposed geographical locations.

Strategies for Development and Deployment of CO_2 Biofixation
- Public Private Partnerships with California state agencies and federal agencies
- Pursuit of Climate Action Registry
- Licensing to other facilities and applications
- Developing and financing of more peaker plants with this technology

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[2] Source: http://www.energy.ca.gov/electricity/gross_system_power.htm, California Energy Commission, California Gross System Power for 2006 in Gigawatt-Hours (GWh), Natural Gas (41.5%), Nuclear (12.9%), Large Hydro (19.0%), Coal (15.7%), Renewable (10.9%)