Attachment 1: Description of Emission Reduction Measure Form

Please fill out one form for each emission reduction measure. See instructions in Attachment 2.

Title: Biofixation of Emissions from Power Generation

Type of Measure (check all that apply):

- ☐ Direct Regulation
- ☐ Market-Based Compliance
- ☐ Monetary Incentive
- ☐ Non-Monetary Incentive
- ☐ Voluntary
- ☐ Alternative Compliance Mechanism
- ☒ Other Describe: **Research & Development**

Responsible Agency: Carbon Capture Corporation (CCC) is currently cooperating with, and seeking advise from, ARB, EPA and CEC.

Sector:

- ☐ Transportation
- ☒ Electricity Generation
- ☒ Other Industrial
- ☒ Refineries
- ☒ Agriculture
- ☐ Cement
- ☒ Sequestration
- ☐ Other Describe:

2020 Baseline Emissions Assumed (MMT CO2E): TBD

Percent Reduction in 2020: TBD

Cost-Effectiveness ($/metric ton CO2E) in 2020: 20

Description: Algae biomass is a promising and potentially cost effective emissions control for existing power generation, especially for carbon dioxide (CO_2) reduction. It is not known what will be the most environmentally beneficial use of the resultant large mass of algae that have "captured" the CO_2 and other emissions. Identified uses include but are not limited to: biodiesel; biogas, fertilizer and aquaculture feed. A life cycle analysis and carbon accounting are needed for this process to help determine best environmental practices and potential for Climate Action Registry for the various biomass uses. CCC has performed several small scale tests (30 kW) with promising results showing CO_2 capture potentials between 10% and 92%. An existing paper describes the capture and sequestration of CO_2 from stationary combustion systems by photosynthesis of microalgae.

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).

Emission Reduction Calculations and Assumptions: A new prototype was tested on 9/4/07 and emissions levels were recorded from a small diesel engine. Spirulina culture water was used as a counter agent in the exchanger. The test results showed a 65% reduction in SO_2, slightly lower than the 79% associated with CO_2. Please note that these preliminary results are provided for discussion purposes only as various exchanger designs continue to be investigated.

Spirulina medium

	Before	After	Reduction [%]
CO_2 [%]	3.09	0.65	79
NO_2 [ppm]	61.5	2.4	96
O_2 [%]	17.1	17.7	3 (increase)
NO [ppm]	44	14	68
CO [ppm]	633	617	2.5
NO_x [ppm]	105	17	84
SO_2 [ppm]	17	6	65
pH			pH drop negligible

At the present time, Carbon Capture is focusing on natural gas applications. SO_2 produced from the odorant in natural gas is not expected to be a significant issue. This will use up some of our alkalinity, but not a significant amount. Sulfur at low levels, like ammonia, is just beneficial to the algae as it uses some of the SO_4 in the medium to build sulfur containing amino acids. The amount of S in the algae is in the fractional % range (dry wt). Sulfur is seldom a limiting nutrient and we expect that the algae will use a few 10's of ppm of SO_x for every % of CO_2 in the stack gas.

Cost-Effectiveness Calculation and Assumptions: TBD

Implementation Barriers and Ways to Overcome Them: 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. CCC research efforts are directly addressing approaches to expand the technology to less sun exposed geographical locations.

Potential Impact on Criteria and Toxic Pollutants: Various reduction levels in NOX, SOX and CO have been observed during testing (see above example). Reductions in PM10 are expected but not yet investigated and ammonia slips are also expected to be used as nutrient by the biological system.

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