Project Archive – Breakthrough Concepts

Project Title	Primary Contractor	Project End Date
Recovery & Sequestration of CO_2 from Stationary Comb. Systems by Photosynthesis of Microalgae	Physical Sciences, Inc.	4/1/2005
Enhanced Practical Photosynthesis CO_2 Mitigation	Ohio University	2/28/2005
CO_2 Sequestration by Mineral Carbonation Using a Continuous Flow Reactor	Albany Research Center	9/30/2003
Advanced CO_2 Cycle Power Generation	Foster Wheeler	12/31/2004
Activation of Carbonation Minerals for CO_2 Sequestration	NETL	2005
Process Design for the Biocatalysis of Value-Added Chemicals from CO_2	University of Georgia	7/31/2007
Determination of Mechanism, Rate, and Catalysts of Magnesium Silicate Carbonation*	LANL	4/15/2003

* Factsheet Not Available

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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

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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

PARTNERS

Physical Sciences, Inc.

University of Hawaii Aquasearch

COST

Total Project Value
$2,361,111

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

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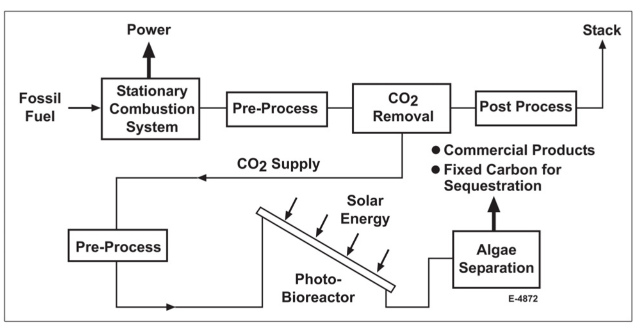
Accomplishments

- 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.

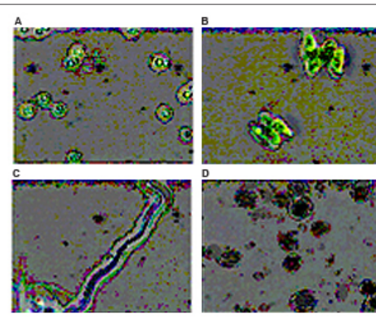
Benefits

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.



Recovery and sequestration of CO_2 from stationary combustion systems by photosynthesis of microalgae



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

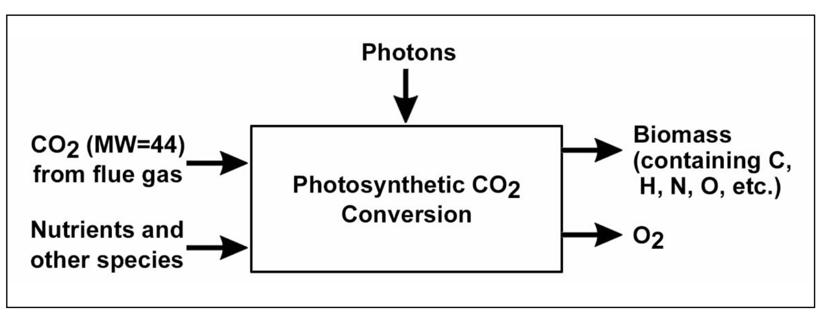
ENHANCED PRACTICAL PHOTOSYNTHETIC CO_2 MITIGATION

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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PARTNER

Ohio University

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.

COST

Total Project Value
$1,369,495

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

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PROJECT facts

Sequestration

01/2005

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

CO_2 SEQUESTRATION BY MINERAL CARBONATION USING A CONTINUOUS FLOW REACTOR

Background

Advanced chemical processing may lead to unique sequestration technologies or to improvements in our understanding of the chemistry involved that will enhance the performance of other sequestration approaches. CO_2 mineralization is the most permanent method for storing CO_2. This approach exploits a carbonation reaction that combines CO_2 with alkaline earth elements (predominantly magnesium, but also iron and calcium) derived from silicates to yield thermodynamically stable solid mineral carbonates. Sufficient alkaline earth silicates exist to dispose of all the CO_2 that could be produced from the world's entire reserves of conventional fossil fuels. CO_2 mineralization mimics natural chemical cycles involving CO_2. Nature has already sequestered approximately 40,000,000 Gt of carbon in the form of mineral carbonates, mostly as $CaCO_3$. These carbonates formed primarily as a result of weathering, in which calcium silicates are altered by carbonic acid in rainwater, releasing calcium ions to rivers and the ocean where carbonates are formed. This process is one of the primary components of the natural carbon cycle. Unfortunately, the natural carbon cycle operates on a time scale too long to accommodate the rapid rate of anthropogenic CO_2 emissions from the use of fossil fuels.

The Albany Research Center (ARC) is working on the development of a continuous flow reactor for the mineral carbonization process. The process has been demonstrated in batch, laboratory-scale reactors over a wide range of conditions, but a continuous flow process is necessary for economic viability. Basically, this process will operate at a relatively high temperature (185ºC) and pressure (2,300 psi) and inject supercritical CO_2 using intense mixing into finely ground minerals held in aqueous suspension to produce stable carbonated minerals. The best reactants identified for carbonation are the magnesium-containing minerals olivine and serpentine. Both minerals show a relatively high reactivity with CO_2, produce readily filterable product slurries, generate products that have good long-term stability, and have wide distribution in sufficient quantities to be good candidates for regional implementation of CO_2 sequestration.

TURNING CO_2 TO MINERALS - Gaseous carbon dioxide can be captured and converted into these environmentally-safe, magnesite minerals. The brown mineral is produced when olivine is used in the reaction; the white powder is produced when serpintine is used.

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Albany Research Center (ALRC)

Arizona State University

Los Alamos National Laboratory

Science Applications International Corporation

COST

Total Project Value
$1,419,100

DOE/Non-DOE Share
$1,419,100/ $0

Primary Project Goal

The primary goal of the proposed research is to develop an economically and environmentally acceptable integrated mineral carbonation process for disposal of CO_2 generated by the combustion of fossil fuels in power-generation plants.

Objectives

Laboratory-Scale Continuous Flow Reactor

- Determine the engineering parametrics
- Incorporate optimized process variables into the reactor testing
- Initiate study for integration of pre- and post-treatment steps with flow reactor design
- Complete detailed material and energy balances for the flow reactor system.
- Assist in the completion of an updated cost evaluation of the Carbonation Process using the flow reactor concept
- Demonstrate process integration or pre- and post-treatment steps in the flow reactor system
- Continue studies on slurry separation and recycle issues

Fundamental Studies

- Finalize slurry density and pH investigations, determining optimum solids content and system pH
- Determine effective solution and solids recycle potential
- Complete the study on the activated, pseudo-amorphous mineral phase
- Identify optimum parametric space for pretreated mineral reactant
- Determine energy requirements for favored mineral pretreatment options

Accomplishments

The process has been demonstrated in batch-type laboratory-scale tests over a wide range of temperatures and partial pressures of CO_2. Over 80% of the reaction can now be completed with in an hour. Research to date has advanced the understanding of the kinetics and important parameters of the reaction, but the development of a continuous reactor is necessary to prove the process on a larger scale. Researchers hope to move from 5 pounds per hour of minerals being processed to 500 pounds per hour and ultimately to 10 tons per hour.

Benefits

The major benefits of CO_2 sequestration by mineral carbonation are:

Long Term Stability - Mineral carbonation is a natural process that is known to produce environmentally safe and stable material over geological time frames. The production of mineral carbonates insures a permanent fixation rather than temporary storage of the CO_2, thereby guaranteeing no legacy issues for future generations.

Vast Capacity - Raw materials for binding the CO_2 exist in vast quantities across the globe. Readily accessible deposits exist in quantities that far exceed even the most of coal reserves.

Potential to be Economically Viable - The overall process is exothermic and, hence, has the potential to be economically viable. In addition, its potential to produce value-added by-products during the carbonation process may further compensate its costs.

PROJECT
facts

U.S. DEPARTMENT OF ENERGY
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NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

03/2006

ADVANCED CO_2 CYCLE POWER GENERATION

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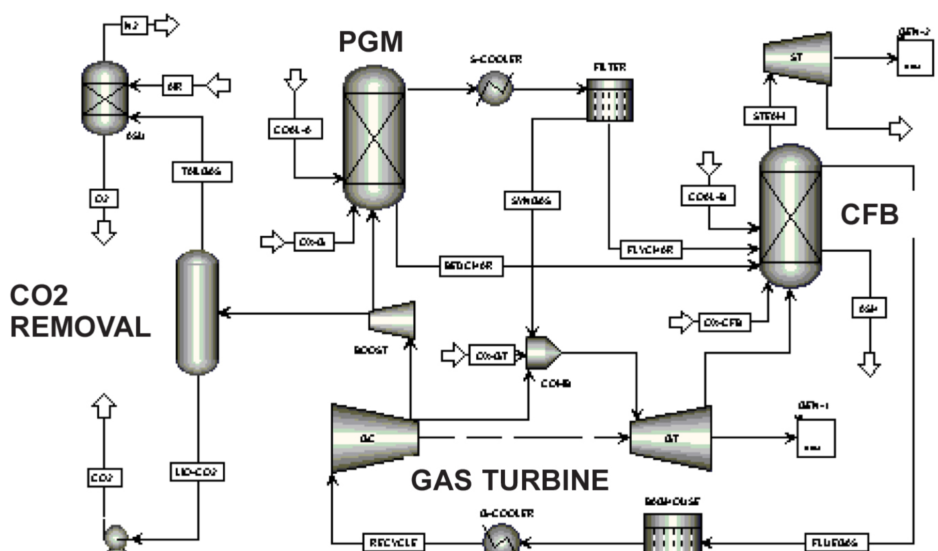
Background

This project will develop a conceptual power plant design based on hybrid fluidized bed technology that can achieve 100% CO_2 capture while avoiding the cost and technical limitations of CO_2 separation from syngas. The plant utilizes the novel concept of using CO_2 as a working fluid within a coal gasification-based powerplant, which efficiently generates power while concentrating CO_2 for sequestration. The first step of the process is air separation, where oxygen is extracted from air for use in both the gasification and combustion processes. Oxygen reacts with coal and steam in a partial gasification module (PGM) to generate syngas and char residue. Both of these fuel streams are then burned with oxygen: The syngas is burned in the combustion turbine to drive a gas turbine generator, and the char is burned in a circulating fluidized bed (CFB) steam generator to make steam for the steam cycle.

The CO_2 is concentrated in the process by recycling the exhaust gas flow, consisting primarily of CO_2, between the CFB combustor and the combustion turbine. As the final step to balance the process, a portion of the pressurized CO_2 rich gas is diverted from the process for sequestration. There is no plant stack and all waste streams including CO_2 from the process are in their most concentrated and manageable form.



PARTNER

Foster Wheeler North America Corp.

COST

Total Project Value
$300,000

DOE/Non-DOE Share
$240,000 / $60,000

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Primary Project Goal

The main goal is to develop an advanced, gasification-based power cycle that produces a concentrated CO_2 stream for sequestration while achieving high plant efficiency and reliability at a competitive cost.

Objectives

The objectives are to optimize the plant process, complete a conceptual design of the plant, and estimate plant capital and operating cost to assess the feasibility of this advanced power technology.

Accomplishments

The Foster Wheeler CO_2 hybrid cycle project has been completed. The key components of the plant are a cryogenic air separation unit (ASU), a pressurized circulating fluidized bed gasifier, a CO_2 powered gas turbine, a circulating fluidized bed boiler, and a super-critical pressure steam turbine.

The process as designed yields an overall plant efficiency of almost 36% while sequestering CO_2. Two of the key project targets were achieved. The process developed had the lowest efficiency penalty for carbon sequestration when compared to alternative methods along with the lowest CO_2 mitigation cost. However, the process failed to achieve the lowest cost of electricity among coal fired alternatives. This was mainly due to the basis of the plant on the pressurized circulating fluidized bed gasifier which is still in developmental stages. The cost of the developmental gasifier is estimated to be greater than IGCC, but there still is a lot of uncertainty in the estimates. Another issue is that the currently available turbines would not be able to handle the CO_2 stream. Current turbines operate on mainly nitrogen streams (from air combustion) and therefore were designed with different thermodynamic limits.

Benefits

This technology offers the following key benefits:

- A completely zero emissions stackless plant that can produce power and a high pressure CO_2 exhaust stream more efficiently than conventional gasification technologies.
- CO_2 sequestration is achieved while avoiding the costly, energy-intensive CO shifting, CO_2 chemical/physical absorption, and CO_2 stripping processes used in conventional gasification technology.
- A wide range of inexpensive coals can be used as fuel because fluidized bed technology is used for both the gasification and combustion processes.
- Minimal water is used in the process because water scrubbing and water gas shift processes are avoided.
- All effluent streams from the process (SO_2, CO_2, NO_x, N_2, H_2O, metals, ash) are concentrated for efficient reuse or disposal.
- The CO_2 exhaust stream is provided inherently at pressure from the process.

P R O G R A M
facts

U.S. Department of Energy
National Energy Technology Laboratory

Mineral Sequestration

07/2000

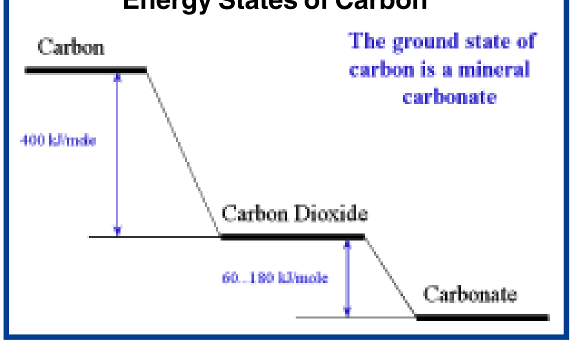
Mineral Carbonation Study Program

Description

The availability of clean, affordable energy is essential for the prosperity and security of the United States, as well as the rest of the world. About 85% of the energy used in the US is derived from fossil fuels, and continued dependence on these fuels is expected well into the 21st century. The continuing demand for energy and the associated rising CO_2 concentration in the atmosphere may have potentially large impacts on climate change. Comprehensive measures, including CO_2 sequestration, would be required to reduce CO_2 emissions while sustaining the demand for energy. Several methods have been suggested for sequestering CO_2, all of which have advantages and disadvantages. Among them, mineral carbonation is a relatively new and less-studied method with potential to sequester substantial amounts of CO_2.

Mineral carbonation, alternately referred to as Mineral Sequestration, is the reaction of CO_2 with non-carbonate minerals such as olivine and serpentine to form geologically stable mineral carbonates. Mineral carbonation could be realized in two ways. First, minerals could be mixed and reacted with CO_2 in a process plant. Second, CO_2 could be injected into selected underground mineral deposits for carbonation, similar to geological sequestration. Using mineral carbonation to reduce CO_2 emissions has many potential advantages such as:

Energy States of Carbon



Mineral Carbonization occurs naturally

Long Term Stability. Mineral carbonates, the product of this process, are known to be stable over geological time frames. This process ensures permanent fixation rather than temporary storage of CO_2, thereby guaranteeing no legacy issues for future generations. Mineral carbonation mimics the natural weathering of rock.

Vast Capacity. The raw materials for binding CO_2 exist in vast quantities across the globe. Readily accessible deposits exist in quantities that far exceed even the most optimistic estimates of coal reserves.

Potential to Become Economically Viable. The overall process is exothermic and, hence, has the potential to become economically viable. In addition, its potential to produce value-added by-products during the carbonation process, such as strategically important metals, may further reduce its costs.

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Albany Research Center
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Arizona State University
Tempe, Arizona

Los Alamos National Lab
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MINERAL SEQUESTRATION HOMEPAGE

http://www.fe.doe.gov/products/gcc/index.html

NETL

Mineral Carbonation Study Program

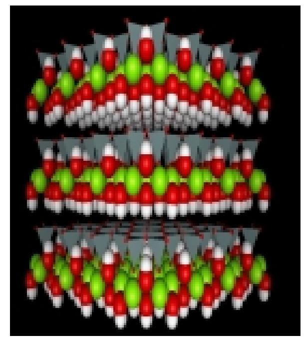
Despite these advantages, mineral carbonation processes will be practical only when two key issues are resolved. First, for sequestration purposes, a fast reaction route that optimizes energy management must be found. Second, issues with respect to the mining and processing activities required for mineral sequestration need to be quantified, especially concerns related to overall economics and environmental impact.

Goals

The primary goal of the mineral carbonation study is to generate a useful knowledge base that can lead to development of mineral CO_2 sequestration methods. To achieve this goal, the reaction mechanisms, heat requirements and environmental interactions must be understood well enough to permit engineering process development. A secondary goal is to acquire knowledge essential to understanding the reactions of CO_2 with underground minerals, in support of the U.S. Department of Energy's geological sequestration programs where CO_2 may be injected to deep saline aquifers or depleted oil or gas reservoirs. Knowledge of the reaction characteristics of CO_2 with various minerals at elevated pressures and temperatures such as those found deep underground will help scientists predict the long-term effects of such practices.

Elements

The team of researchers comprising this working group are pooling their knowledge and experimental capabilities in order to effectively conduct the structured program outlined below.



$Mg_3Si_2O_3(OH)$ - Atomic representation of serpentine structure (commonly called Lizardite)

***Study of Carbonation Reactions*.** Progress to date has been extremely encouraging. It has been found that finely ground serpentine $Mg_3Si_2O_5(OH)_4$, or olivine Mg_2SiO_4, will react with CO_2 in solutions of supercritical CO_2 and water to form magnesium carbonate $MgCO_3$. The reaction can be summarized as

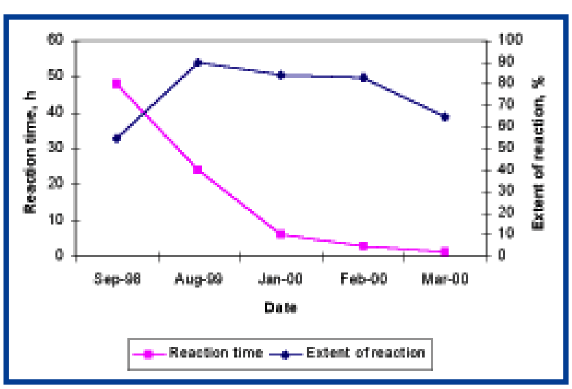
$$1/3\ Mg_3Si_2O_5(OH)_4 + CO_2 \text{ -----> } MgCO_3 + 2/3\ SiO_2 + 2/3\ H_2O$$

When the program first started, it required 24 hours to produce a 50% carbonation level using an olivine feedstock, reaction temperatures of 150-250°C and pressures of 85-100 bar. Through careful control of solution chemistry, the process has been accelerated so that 84% conversion of olivine can be achieved in just 6 hours. Furthermore, when heat pretreated serpentine is reacted using the same enhanced reaction process, approximately 80% conversion occurs in less than an hour. Carbonation studies are continuing utilizing highly instrumented reactors and atomic level simulations to optimize reaction conditions, and explore the use of catalysts and alternative feedstocks.

***System Feasibility*.** A life cycle assessment is under way to establish the feasibility of the baseline mineral sequestration concept with respect to system costs, development requirements and environmental attributes.

***Feedstock Characterization*.** Specific mineral deposits are being identified and characterized based upon potential co-location of mines and sequestration plants with fossil power plants. In addition, potential feedstock sources from industrial byproducts and waste streams are being examined.

These efforts are being conducted as part of Fossil Energy's Advanced Research and Technology Development efforts. The Mineral Carbonation Program is being managed through the National Energy Technology Laboratory's Environmental Product Division and is supported by the Coal Utilization Science, University Coal Research, and the Advanced Metallurgical Processes programs. The activities of the working group are being coordinated by the CUS program. Note that the group is seeking to interact with other interested researchers and industry stakeholders as a means to increase overall program scope and impact.



Mineral carbonation reaction time has been reduced from 48 hours to one hour over the period from Sept. 1998 to March 2000 at the Albany Research Center.

PROJECT facts

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

Sequestration

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Process Design for the Biocatalysis of Value-Added Chemicals From CO_2

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Background

Organic compounds available from U.S. agricultural enterprises include glycerol, a renewable material generated as a by-product in the production of biodiesel, whose production volume is anticipated to increase significantly, and glucose, the primary carbohydrate generated from agricultural enterprises in the U.S., such as corn wet-milling. This project is studying the production of a suite of specialty chemicals by biocatalytic fixation of CO_2 and co-substrates, such as glycerol and glucose. Although several chemical products can be produced using the sequestration technology being developed by this project, the focus of this study is on succinic acid. Recent advances in the metabolic engineering of the production microbes have made feasible the commercial biosynthesis of succinic acid from CO_2 and these co-substrates.

The biochemical pathways leading to succinic acid are similar in structure to those of *archaea*. However, unlike many species of *archaea*, the bacterium used in this project, can attain a high cell density in a short time and thereby provide high productivities, does not have fastidious media requirements, is well characterized genetically, does not require light to generate ATP, and is immediately amenable to process scale-up. Moreover, the proposed biocatalytic process is designed to operate under non-growth (stationary phase) conditions. This permits a high product yield to be achieved and minimizes the formation of excess biomass.

Primary Project Goal

The primary goal of this project is to produce a suite of specialty chemicals by biocatalytic fixation of CO2 with other inexpensive organic substrates, such as glycerol and glucose. The primary product from this operation is succinic acid.

PARTNER

University of Georgia Research Foundation, Inc.

COST

Total Project Value
$384,275

DOE/Non-DOE Share
$384,275 / $0

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Objectives

The objectives of this project are to:

- Modify the bacterial strain to make it suitable for industrial applications.
- Evaluate process robustness.
- Evaluate succinic acid production as a function of CO_2 mass transfer.
- Determine the effect of other process variables, such as pH and H_2 in the gas stream.
- Determine the effect of NO_X and SO_X and other potential inhibitors in flue gas.
- Optimize the fermentation medium to achieve and maintain a high cell density which supports succinic acid production.
- Develop a reactor design that optimizes CO_2 mass transfer and produces succinic acid at high rates and yields.

Benefits

This biological reaction to sequester CO_2 promises to be a practical way to convert CO_2 into value-added chemicals. An advantage of this process is the potential to use flue gas directly in the succinic acid production process and, thus, avoid the need for CO_2 capture and transport. The anticipated future application of the project will result in the synthesis of other chemical products from CO_2, such as formic acid, malic acid, and fumaric acid. This research will form the basis of a biorefinery approach for the production of value-added chemicals from CO_2 and serve as a niche process for CO_2 sequestration.

Accomplishments

- A strain has been developed which prevents the formation of ethanol as a by-product, and therefore a step which would generate CO_2 has been removed.
- The effect of pH and temperature on the CO_2 sequestration has been studied, with the result that the process can operate in the temperature range of 30 °C to 39 °C and the pH range of 6.2 to 7.0 without a deleterious effect on sequestration rate.
- An inexpensive defined media has been developed which promotes the growth of the microorganism, and permits subsequent sequestration. The process using this media has consistently attained a volumetric CO_2 sequestration rate of about 700 mg/Lh.