# Environment and Natural Resources Trust Fund
# 2020 Request for Proposals (RFP)

**Project Title:** **ENRTF ID: 184-E**

Carbon Capture through Biological Mineralization

**Category:** E. Air Quality, Climate Change, and Renewable Energy

**Sub-Category:**

**Total Project Budget: $** 292,500

**Proposed Project Time Period for the Funding Requested:** June 30, 2023 (3 yrs)

**Summary:**

We will utilize emerging technologies to capture and transform carbon dioxide into mineralized insoluble carbonates for use in secondary markets such as cement production.

**Name:** Brett Barney

**Sponsoring Organization:** U of MN

**Job Title:** Professor

**Department:** Bioproducts and Biosystems Engineering

**Address:** 1390 Eckles Ave

St. Paul MN 55108

**Telephone Number:** (612) 562-3061

**Email** bbarney@umn.edu

**Web Address:** http://barneybioproductslab.cfans.umn.edu/brett-barney

**Location:**

**Region:** Statewide

**County Name:** Statewide

**City / Township:**

**Alternate Text for Visual:**

Image depicting carbon capture and conversion cycle

| | | | |
|---|---|---|---|
| _____ Funding Priorities | _____ Multiple Benefits | _____ Outcomes | _____ Knowledge Base |
| _____ Extent of Impact | _____ Innovation | _____ Scientific/Tech Basis | _____ Urgency |
| _____ Capacity Readiness | _____ Leverage | _____ TOTAL | _____% |

**PROJECT TITLE: Carbon Capture through Biological Mineralization**

**I. PROJECT STATEMENT**

**CONCEPT**. We will utilize emerging technologies to transform carbon dioxide into mineralized insoluble carbonates. These mineral products slowly precipitate under natural conditions, but the precipitation can be enhanced using engineering principles to rapidly separate these into benign and value-added compounds such as limestone. Our goals will be to couple biological and engineering processes to develop a process that captures carbon dioxide in an efficient manner to make a safe product with the further potential for commercial value.

**BACKGROUND.** Concentrations of carbon dioxide ($CO_2$) have been steadily increasing in the atmosphere, with an increase in the rate of accumulation starting with the industrial revolution. Returning concentrations of atmospheric carbon to pre-industrial age levels will require the development of cheap and sustainable methods to collect and concentrate this carbon on a large scale. Techniques have been developed that capture and compress the $CO_2$ for injection into deep underground caverns or abandoned mines, but these are susceptible to sudden release based on geological events or failure of these engineered storage sinks. For safe long-term storage of this atmospheric carbon, solid forms of carbon storage such as calcium carbonate, the primary constituent of seashells and limestone, provide the most ideal alternative. Additionally, these carbonates have potential application in products such as concrete and other building materials, giving them an added value as a potential to improve the economic value of this approach through secondary markets.

Biology utilizes simple processes to increase the conversion of $CO_2$ into bicarbonate and carbonate to improve fundamental processes such as photosynthesis and the processes used by certain marine species to make elaborate seashells. Once these altered ionic forms of $CO_2$ come in contact with certain cations such as calcium, this results in precipitation of the newly formed mineral. This process of precipitating the carbonates can be further increased by mixing in solutions that increase the rates of precipitation. Coupled to a simple process to separate the solid precipitate from the liquid solution, the final product can be safely stored for centuries, or used in other building and engineering projects.

**GOAL**. The overall goal of this project is to develop a technology that rapidly traps $CO_2$ by converting the atmospheric gas into an insoluble and stable solid and rapidly separating the solid from solution. The fundamental aspects of this technology are well established, but the feasible application of the processes is hindered by a lack of optimization to engineer the process in the most effective manner. Our project will address issues of enzyme stability in alkaline conditions, while enhancing precipitation through engineering approaches. The final product will be a process that rapidly converts atmospheric carbon into a benign mineral.

**II. PROJECT ACTIVITIES AND OUTCOMES**

**Activity 1:** ***Enhance Biological Processes to Convert $CO_2$ into Carbonates*** **Budget: $ 160,000**

Processes that convert $CO_2$ into the ions bicarbonate ($HCO_3$) and carbonate ($CO_3$) through the action of the enzyme carbonic anhydrase are well established in the literature, and biological enzymes that perform this reaction are among the most efficient enzymes known. In some cases, these processes lead to the formation of insoluble carbonates, such as calcium carbonate ($CaCO_3$), which is more commonly known as limestone. Other ions can also be used to precipitate the carbonate.

| Outcome | Completion Date |
|---|---|
| 1. Develop systems to produce high yields of active extracellular alkaline carbonic anhydrase to rapidly convert $CO_2$ into bicarbonate and carbonate. | Dec 15, 2022 |
| 2. Identify ideal water/solvent systems to enhance the precipitation of carbonates and bicarbonates. | June 1, 2021 |
| 3. Engineer enzyme stability within different water/solvent mixtures based on modern biochemical methods and high-throughput screens | June 1, 2023 |

**Activity 2:** ***Engineer Carbon Capture Technologies to Collect Atmospheric $CO_2$*** **Budget: $ 132,500**

The second aim of this project will be to develop technologies to engineer a complete process that scrubs atmospheric $CO_2$ through a simple reactor system to partition the carbon into a mineral form for simple separation. Systems will be designed to minimize cost and take advantage of sustainable technologies while also developing a continual process to fully capitalize on the potential of a highly evolved biological process

| Outcome | Completion Date |
|---|---|
| 1. Design initial systems to take advantage of clean, high $CO_2$ exhaust streams such as those produced by breweries to enhance the potential for success and share aspects of these technologies with the general public. | March 15, 2022 |
| 2. Combine technologies developed under Activity 1 with reactors designed as part of Outcome 1 from this activity (Activity 2) to enable reactors that can collect $CO_2$ from the atmosphere in a simple pilot-scale reactor system. | May 30, 2023 |

**III. PROJECT PARTNERS:**

The research team includes Professor Brett Barney from the Department of Bioproducts and Biosystems Engineering and the BioTechnology Institute at the University of Minnesota, who will oversee the project. Professor Barney's lab works with model bacteria that convert $CO_2$ into mineral carbonates such as limestone. Professor Barney also has many years of experience in large-scale process engineering. Professor Bo Hu from the Department of Bioproducts and Biosystems Engineering and BioTechnology Institute at the University of Minnesota is a chemical engineer with experience in process engineering. We also envision developing multiple partnerships with various local industries to promote these technologies, including concrete producers, breweries and glass manufacturers. Our project will also include an educational component, reaching out to various K-12 educators to educate students about potential technologies to capture $CO_2$ and convert it into valuable products. Importantly, we realize that the best way to encourage private industry to adopt these technologies is to make it profitable to employ these technologies. Assessing the economic value and engaging industries to invest in new technologies will require substantial improvements to these processes, which is the primary goal of this project

**IV. LONG-TERM- IMPLEMENTATION AND FUNDING:**

We expect this proposed work to be the initiation of a long-term project. The goals of this project are aggressive and would be highly impactful if successful. The development of technologies that capitalize on highly evolved and efficient biological processes provide both an incentive and a roadmap that would lead to successful implementation. This project and similar proposals need to be pursued at a global scale. The technology we propose to develop should have a low operating cost that can be minimized or even eliminated based on the development of new markets for the final product. Further funding could come from a variety of federal agencies, including the Department of Energy, the Advanced Research Projects Administration – Energy (ARPA-E) or a number of different investors with interests in lowering global carbon emissions or producing carbonates for use in their own industrial applications to offset the carbon footprints.

**V. TIME LINE REQUIREMENTS:**

This project has a target for completion of 3 years. Preliminary studies to identify specific target enzymes for the studies described above are already underway, but would be substantially expanded once the project is funded. Further support would be sought through additional funding sources based on early successes of the project.

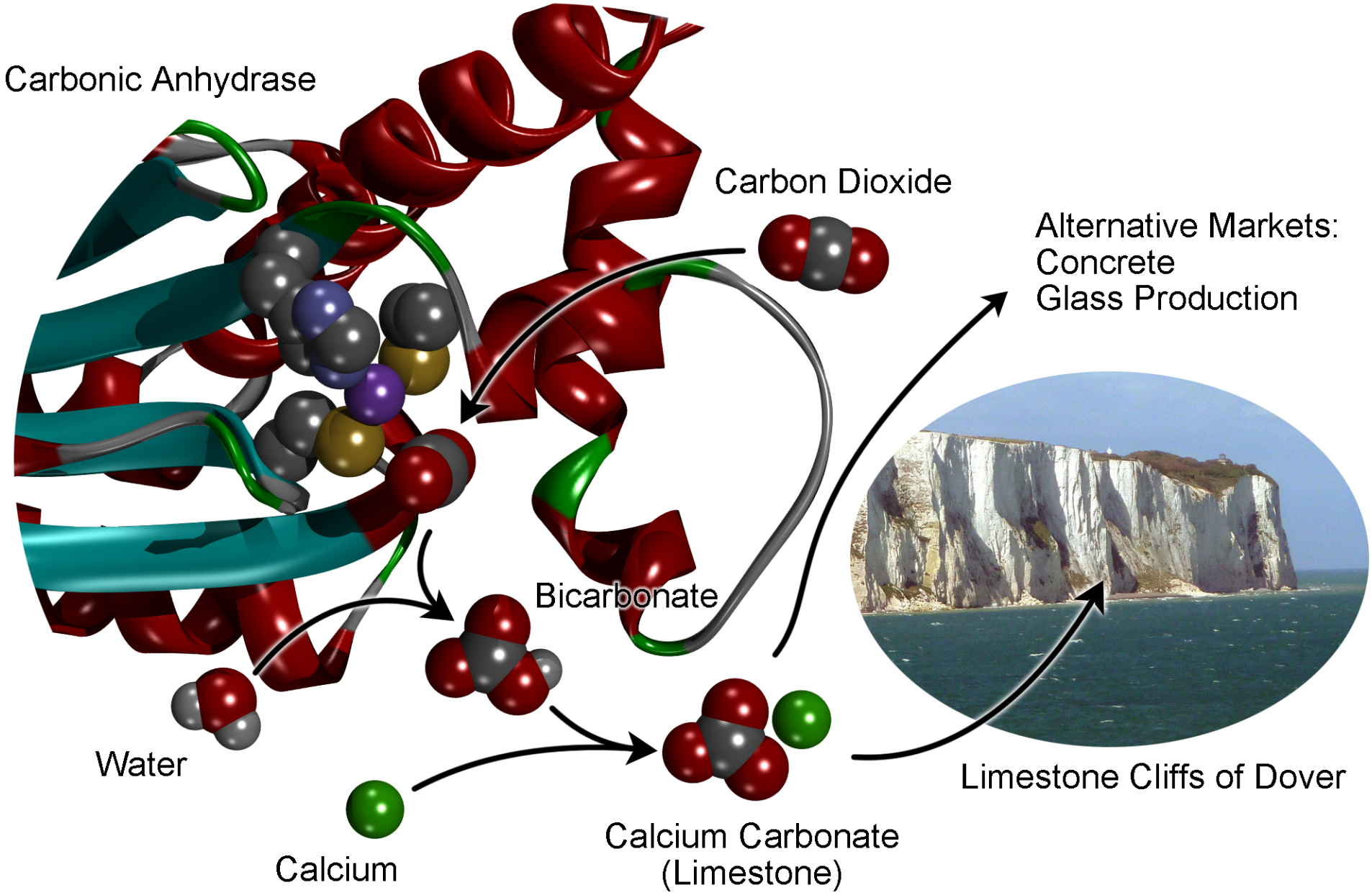
**Attachment A: Project Budget Spreadsheet**
**Environment and Natural Resources Trust Fund**
**M.L. 2020 Budget Spreadsheet**
**Legal Citation:**
**Project Manager: Brett Barney**
**Project Title: Carbon Capture through Biological Mineralization**
**Organization: University of Minnesota**
**Project Budget: $292,500**
**Project Length and Completion Date: 3 years - 06/30/2023**
**Today's Date: 4/11/2019**

| ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET | Budget | Amount Spent | Balance |
|---|---|---|---|
| **BUDGET ITEM** | | | |
| **Personnel (Wages and Benefits)** | $ 240,000 | $ - | $ 240,000 |
| Brett Barney, Project Manager (73.5% salary, 26.5% benefits), Associate Professor, 9 Month Appointment, Summer Salary; 4% FTE (0.5 month) for 3 years, $24,000 | | | |
| Bo Hu, co-Project Manager (73.5% salary, 26.5% benefits), Associate Professor, 9 Month Appointment, Summer Salary; 4% FTE (0.5 month) for 3 years, $24,000 | | | |
| 1 Graduate Research Assistant, UMN (Twin Cities), Laboratory Experiment Data Analysis, supervised by Barney and Gralnick (65% salary/35% fringe); 50% FTE for 3 years, $148,000 | | | |
| Undergraduate Research Assistants, UMN (Twin Cities), Laboratory Experiment, Supervised by Barney and Hu (100% salary) approximately 800 hours per year, 3 years , $45,000 | | | |
| **Professional/Technical/Service Contracts** | | | |
| | $ - | $ - | $ - |
| **Equipment/Tools/Supplies** | | | |
| Laboratory Supplies: General Laboratory Chemicals, Media, and Reagents ($400 per month) and Kits for Performing Routine Molecular Biology ($400 per kit), Analytical Reagents, DNA Synthesis of Primers ($100 per month), Liquid Nitrogen for Strain Storage ($400 per year). Combined laboratory supplies for the labs for both PIs (Barney and Hu). | $ 45,000 | $ - | $ 45,000 |
| Lab services - DNA Sequencing for Enzyme Optimization Studies ($1500 per year). | $ 4,500 | | $ 4,500 |
| **Capital Expenditures Over $5,000** | | | |
| | $ - | $ - | $ - |
| **Fee Title Acquisition** | | | |
| | $ - | $ - | $ - |
| **Easement Acquisition** | | | |
| | $ - | $ - | $ - |
| **Professional Services for Acquisition** | | | |
| | $ - | $ - | $ - |
| **Printing** | | | |
| | $ - | $ - | $ - |
| **Travel expenses in Minnesota** | | | |
| Travel by the project managers and graduate students between the Twin Cities campus and various field sites across Minnesota, to be reimbursed by the University Compensation Plan. | $ 3,000 | $ - | $ 3,000 |
| **Other** | | | |
| | $ - | $ - | $ - |
| **COLUMN TOTAL** | $ 292,500 | $ - | $ 292,500 |

| SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT | Status (secured or pending) | Budget | Spent | Balance |
|---|---|---|---|---|
| **Non-State:** | | $ - | $ - | $ - |
| **State:** | | $ - | $ - | $ - |
| **In kind: Unpaid Indirect Costs** | | $ 132,000 | $ - | $ 132,000 |

| Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS | Amount legally obligated but not yet spent | Budget | Spent | Balance |
|---|---|---|---|---|
| | | $ - | $ - | $ - |

# Carbon Capture through Biological Mineralization



**Project Manager Qualifications**

**Brett Barney, Project Manager**

**Education:**

Ph.D. Biochemistry, Arizona State University, 2003

B.S. Professional Chemistry, Utah State University 1993

**Work and Research Experience:**

2015 – Present Associate Professor, Bioproducts and Biosystems Engineering (UMN)

2017 – Present Director of Graduate Studies, BBSEM Program (UMN)

2015 – Present Director of Graduate Studies, Microbial Engineering Program (UMN)

2010 – Present Faculty Member, BioTechnology Institute and Microbial and Plant Genomics Institute (UMN)

2009 – 2015 Assistant Professor, Bioproducts and Biosystems Engineering (UMN)

2003 – 2009 Research Assistant Professor and USDA Postdoctoral Fellow (USU)

1999 – 2003 Research Assistant and NSF Fellow, Department of Chemistry and Biochemistry (ASU)

1993 – 1999 Fiber Laboratory Manager, Research Chemist, Senior Laboratory Technician and Associate Chemist, Fresenius Medical Care, Ogden, Utah

1991 – 1993 Research Technician, Utah Water Research Laboratory (USU)

**Bo Hu, co-Project Manager, Professor, Department of Bioproducts and Biosystems Engineering (UMN)**

Bo brings expertise in chemical engineering approaches that will be key to the second activity of the proposal.

Dr. Barney's laboratory works with metalloenzymes involved in important biological processes, including nitrogen fixation, photosynthesis and carbon sequestration. Dr. Barney has 30 years of experience in both basic and applied research in both academia and industry, including experience managing projects and laboratories in a range of settings. Previous research funding has come from the National Science Foundation (NSF), the United States Department of Agriculture (USDA), the United States Department of Energy (DOE), the Defense Advanced Research Projects Agency (DARPA), Minnesota's Discover, Research and InnoVation Economy (MnDRIVE) and the Initiative for Renewable Energy and the Environment (IREE).

The Barney laboratory is housed in the Cargill building for Microbial and Plant Genomics at the University of Minnesota. The Cargill building was designed with the intention to promote interdisciplinary collaborations and provide a shared lab space for each floor, which facilitates flexible group sizes. This large laboratory space is designed around a shared communal format, with various rooms available for utilization for specific experiments. The laboratory contains the primary equipment to perform this research project, including facilities to cultivate various bacteria, autoclaves, analytical instrumentation for analysis (gas chromatography, spectrophotometers, and balances), thermocyclers for PCR reactions, centrifuges, electrophoresis equipment and various incubators. Additional facilities include the Biotechnology Resource Center, the Genomic Sequencing Center and a broad range of additional analytical laboratories which are available as pay services.

**Organization Description**

Dr. Brett Barney (PI) has been a professor with the Department of Bioproducts and Biosystems Engineering at the University of Minnesota since 2009. The Bioproducts and Biosystems Engineering Department serves as a core department combining Agricultural Engineering, Biological Engineering and Environmental and Ecological Engineering. The University of Minnesota provides a range of facilities and sufficient laboratory space to perform each of the activities described in this proposal. Additionally, controlled environments including greenhouse space sufficient for this work is conveniently located next door to Dr. Barney's laboratory space. UMN Sponsored Projects Administration (SPA) is the entity authorized by the Board of Regents to manage project agreements with the LCCMR program.