Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-392

Proposal Title: A Novel CO2-Reducing Cement Made from Minnesota Wastes

Project Manager Information

Name: Carolyn Dry

Organization: Designs by Natural Processes, Inc.

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Project Basic Information

Project Summary: Produce an environmentally beneficial novel cement made from Minnesota industrial wastes that lessens impacts on water quality, eases pressure on landfills, and creates positive economic value while reducing CO2 release.

Funds Requested: $290,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro, Central, NE, SE,

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The opportunity is to produce a novel cement made from problematic Minnesota wastes like municipal water treatment plant sludge, ash from coal-fired power plants and solid waste incinerators, and mining and quarrying byproduct materials while reducing CO2 released in cement making. The ash and sludge sources alone generate hundreds of thousands of tons annually, while mining and quarrying operations can generate millions of tons of difficult-to-use mineral fines. These materials take up space, put a strain on landfills, and have significant disposal costs. But these waste materials can also be the raw materials for a new and novel Minnesota cement. The manufacture of conventional portland cement is energy-intensive and releases one ton of CO2 per ton of cement – and 8% of the world's CO2 – half of which due to the combustion of fuel during cement's high-temperature production. Our proposed Minnesota cement will require no energy-intensive heating, will take up CO2 during its manufacture, and will be made using ash, with spent lime sludge from water treatment plants and mining byproducts being the other major ingredients. Key benefits are that we reduce disposal costs, reduce CO2 production, and derive economic return from Minnesota-based wastes.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

Based on our current U.S. Department of Energy (DOE) research project to add wastes to conventional portland cement (to reduce energy use and CO2 release), we will go a step further and develop a new product – a Minnesota cement – made entirely from waste materials found in Minnesota, which will save landfill space and reduce atmospheric CO2. Our novel cement will be designed to take up the greenhouse gas CO2 during manufacture with no intensive heating, using ash wastes of coal-fired utilities and municipal solid waste facilities, lime sludge/filter cake from water treatment plants, and mining wastes such as taconite tailings and industrial mineral silica sand fines. The main benefit is turning wastes into useable products rather than having them impact the environment. The financial benefits are that we create a value-added product while reducing excessive material-handling, waste disposal, and stockpiling costs. Related benefits include:

- saving transportation costs of importing cement
- reducing the high CO2 impact of making conventional cement by developing a cement that takes up CO2 instead
- changing people's perceptions about how to make the best use of resources we consume and finding value in the wastes that are produced as a result of that consumption

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The proposed project envisions protecting, conserving, preserving, and enhancing the state's natural resources in the following ways:

- reduce wastes by beneficially using them (conservation), and by doing so, reduce attendant environmental problems (e.g., potential groundwater contamination) associated with the handling and disposal of waste materials (protection);
- sequester CO2, chemicals, and heavy metals with a new cement product that does not require externally produced conventional raw materials for its manufacture (protection and preservation); and
- reduce the impact on landfill space (preservation).
- create a net economic benefit from waste materials that are typically a net cost (conservation and enhancement).

Activities and Milestones

Activity 1: Obtain and characterize wastes; Determine best recipes; Process combinations; Test specimens physically, for CO2 uptake, and leachate; Quantify environmental benefits

Activity Budget: $195,000

Activity Description:
We will collaborate with various candidate industries and utilities whose wastes will be used as chemical components for the cement. Collaborators include coal ash producers, municipal solid waste incinerator ash generators, water treatment plants, and mineral producers. We will review and compile technical information provided by each waste source and obtain adequate quantities of representative waste materials. After receiving the waste materials, each will undergo chemical, physical, and mineralogical characterization to establish baseline parameters and identify potential risks. A design of experiments factor study will determine the most promising combinations of materials and the number of experimental samples to make. Based on the project team's considerable experience with waste cements and mineral byproducts, we will formulate the best recipes for this Minnesota waste-derived cement. Specimens will be:

- prepared and tested according to national standards for cement (e.g., ASTM compressive strength tests);
- tested to determine how much CO2 is taken up during cement hardening (using gas chamber and gas analyzer and potentially stoichiometry and mass balance calculations); and
- subjected to leaching tests to determine if any chemicals will be released and compared to piles of waste in disposal sites.

From this work, best recipes and processes will be selected.

Activity Milestones:

Description	Completion Date
Obtain and characterize wastes (power plant and incinerator ash; water treatment plant sludge; mineral fines)	2021-12-31
Use design of experiments factor study and project team's experience to guide recipe development	2021-12-31
Fabricate specimens based on Milestone 1 and 2 findings, and determine CO2 uptake	2022-03-31
Specimen testing: ASTM strength testing; leachate characterization; cement composition using electron microprobe analysis	2022-09-30
Select best novel cement recipes and processes based on Milestones 1-4, and quantify environmental benefits	2022-12-31

Activity 2: Assess manufacturing issues and any other issues; assess economics; plan and make recommendations for scale up; produce journal-ready final report

Activity Budget: $95,000

Activity Description:
In any project there are unknown and unforeseen challenges and drawbacks which present themselves as there is scale up and application into the actual environment and dealing with various stakeholders. In this project we will proceed to plan scale up and application in an actual manufacturing setting so that these types of issues can be addressed as proactively as possible. Some of these issues might be variability in waste materials composition, wear on mixing machinery, need for capital equipment investment, and environmental and risk management controls. The selected best recipes and process will be presented to one or more potential manufacturers in Minnesota. Plans will be made to commercialize this product and estimations made of the beneficial environmental and economic impacts. A final report will be made to LCCMR and other stake holders. The final report will be the basis for producing a peer-review journal article for publication and dissemination. Follow-up technology implementation and funding strategies includes private and public sector partnering at the regional and national level (e.g., SBIR, ARPA-E, NSF).

Activity Milestones:

Description	Completion Date
Examine and try to resolve any problems with adaptive and proactive project management	2023-03-31
Select best recipes and process(es); present to potential manufacturers; assess environmental and economic impacts	2023-03-31
Final report to LCCMR and other stake holders; peer-reviewed journal article for publication and presentation	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Kyle Hinrichs	City of Mankato	Mr. Hinrichs is Operations Foreperson for the City of Mankato's Water Treatment Plant, a provider of the project's spent lime sludge/cake. Mr. Hinrichs will be consulted with during the project to provide technical and regulatory advice.	No
Matt Radzak	Minnesota Power	Provide technical input, project guidance/assistance, access to coal ash and related coal ash technical information, and expertise about coal ash, including environmental and regulatory considerations; material collection and shipping.	No
Lawrence Zanko	LZanko, Inc.	Project co-management and technical support.	Yes
Tumer Akakin	Aggregate Ready Mix Association of Minnesota	Project and technical guidance and assistance related to the industrial minerals sector and mineral source producers.	No

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

Plans will be made to implement and commercialize the technology and resulting products. Follow-up technology implementation, commercialization, and funding strategies includes private and public sector partnering and funding at the regional and national level (e.g., SBIR, ARPA-E, NSF), and/or with Minnesota waste manufacturers and companies.

Project Manager and Organization Qualifications

Project Manager Name: Carolyn Dry

Job Title: PhD, President

Provide description of the project manager's qualifications to manage the proposed project.

Carolyn Dry, PhD, is president of Designs by Natural Processes, Inc. She is an emeritus full professor from the University of Illinois, Champaign, Illinois where she taught and did materials research focusing on cement and concrete for 20 years. Before that she taught at MIT and other universities. She graduated with a bachelors degree in architecture with distinction from U MN, a masters from Texas A and M., and a PH.D. from Virginia Tech in 1990. She has published hundreds of papers on cements, concrete, and other materials, has thousands of citations and some 24 patents. Since 2003 she retired from teaching and founded her small business. The business has been awarded several SBIR grants each of which sent to Phase 3 and the largest RIF grant given in one year for 3 million dollars.

Dr. Dry's project management will be supported by Lawrence Zanko (LZanko, Inc.) Mr. Zanko is based in Two Harbors, Minnesota, and offers consulting services based on over 35 years of minerals industry experience, including over 30 years of geological, mineral resource, and minerals industry-related applied research while with the University of Minnesota's Natural Resources Research Institute (NRRI) in Duluth, MN, including beneficial use of mineral-based byproducts generated by mining and other industrial activities, with an eye on their potential for value-added product development and innovative technology uses, and consideration of their potential environmental impact. Mr. Zanko received a Master of Geological Engineering, University of Minnesota, Twin Cities (UMTC); Bachelor of Geological Engineering (UMTC); and B.S. Microbiology (UMTC).

Organization: Designs by Natural Processes, Inc.

Organization Description:

Since 2003 the company has been developing materials that improve the environment. Based on many years when the owner was an academic, the company pursued materials that use waste, self repair, self sense, recycle themselves, and improve the environments for others. The projects developed include making structural panels from coal fly ash to prevent the ash's dangerous chemicals from entering the groundwater but instead sequester them, developing self repairing airplane wings that are lighter and reduce the planes fuel use, self repairing walls that last longer, self repairing concrete bridges, a coating for concrete that absorbs greenhouse gases and releases oxygen, safe recycling of pre-stressed bridge girders. In a current project funded by the US Department of Energy's high level program called ARPA E we are developing an additive to go into the strongest and most durable portion of cement so that the over production of cement will use less energy and therefore produce less CO2. Our material may take up CO2. It will use cement company equipment as is. The project proposes to use some wastes from Minnesota. The team was put together by Carolyn Dry and includes a university, a DOE lab and a cement company.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Dr. Carolyn Dry		Project Manager; Develops new cement and leads research effort			0%	0.5		$95,000
Research Associate		Organize research and make/test samples under Dr. Dry's direction			0%	0.6		$30,000
Research Assistant		Make and test samples under the direction of Dr. Dry			0%	0.6		$25,000
							Sub Total	**$150,000**
Contracts and Services								
LZanko, Inc.	Sub award	Co-management role as Dr. Dry's principal project collaborator.				0.5		$60,000
Natural Resources Research Institute (NRRI)	Professional or Technical Service Contract	Raw material safety screening/characterization to identify potential chemical or mineralogical issues prior to their handling; sample preparation and blending; particle size, chemical, and mineralogical characterization; leachate testing of raw materials and finished products; kiln heating; and selected physical tests of product specimens (e.g., compressive strength); GIS mapping.				0		$35,000
							Sub Total	**$95,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Grinder/pulverizer	For grinding and pulverizing raw materials to optimal particle size					$5,000
	Tools and Supplies	Sieve set (stacking set of sieves)	For sieving raw materials to achieve desired particle size distribution for cement production					$2,000
	Tools and Supplies	CO2 tanks (5) at $200/tank	To provide CO2 for cement fabrication and for determining CO2 taken up by the novel process					$1,000
	Tools and Supplies	Laboratory supplies for kilns, etc.	Consumables, insulation, replacement thermocouples, heating vessels, etc.					$5,000

							Sub Total	**$13,000**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	GSA vehicle mileage and per-diem rates for meals and overnight travel/lodging, typically to non-Metro locations.	Travel to waste producers and project collaborators for meetings and material acquisition					$6,000
							Sub Total	**$6,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Peer-review journal publication cost	For dissemination of project findings					$2,000
							Sub Total	**$2,000**
Other Expenses								
		Electron Microprobe Laboratory Analyses	For detailed mineralogical and microscopic analysis of raw materials and cement products					$5,000
		Shipping	To cover raw material and sample shipping costs					$1,000
		Certified analytical laboratory	Chemical analysis of raw materials and cement products @$150/sample, 20 samples					$3,000
		Certified cement/concrete testing laboratory	Verification/certification testing of cement specimens (entails multiple ASTM test methods per specimen)					$15,000

							Sub Total	**$24,000**
							Grand Total	**$290,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Designs by Natural Processes, Inc. (DNP) cost share.	DNP will supplement the LCCMR request with its own resources and personnel time.	Pending	$20,000
			Non State Sub Total	**$20,000**
			Funds Total	**$20,000**

Attachments

Required Attachments

Visual Component

File: dfe91868-c9d.pdf

Alternate Text for Visual Component

The map of Minnesota shows the locations of sources for material components for the cement made of industrial byproducts/waste.. It includes locations of coal ash, solid municipal waste ash, water treatment plants, and mining and some mineral operation waste locations It also lists the benefits of making this type of cement and a graphic showing its sustainability There are photos of ash, lyme cake and mineral fines such as as limestone and taconite tailings.

Optional Attachments

Support Letter or Other

Title	File
letter from Minnesota Power	11326cd3-fec.pdf
Letter of Support from Municipal Water Treatment Plant-Mankato	590d10f2-3dd.pdf
Aggregate & Ready Mix Association of Minnesota letter of support	392482fa-18f.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

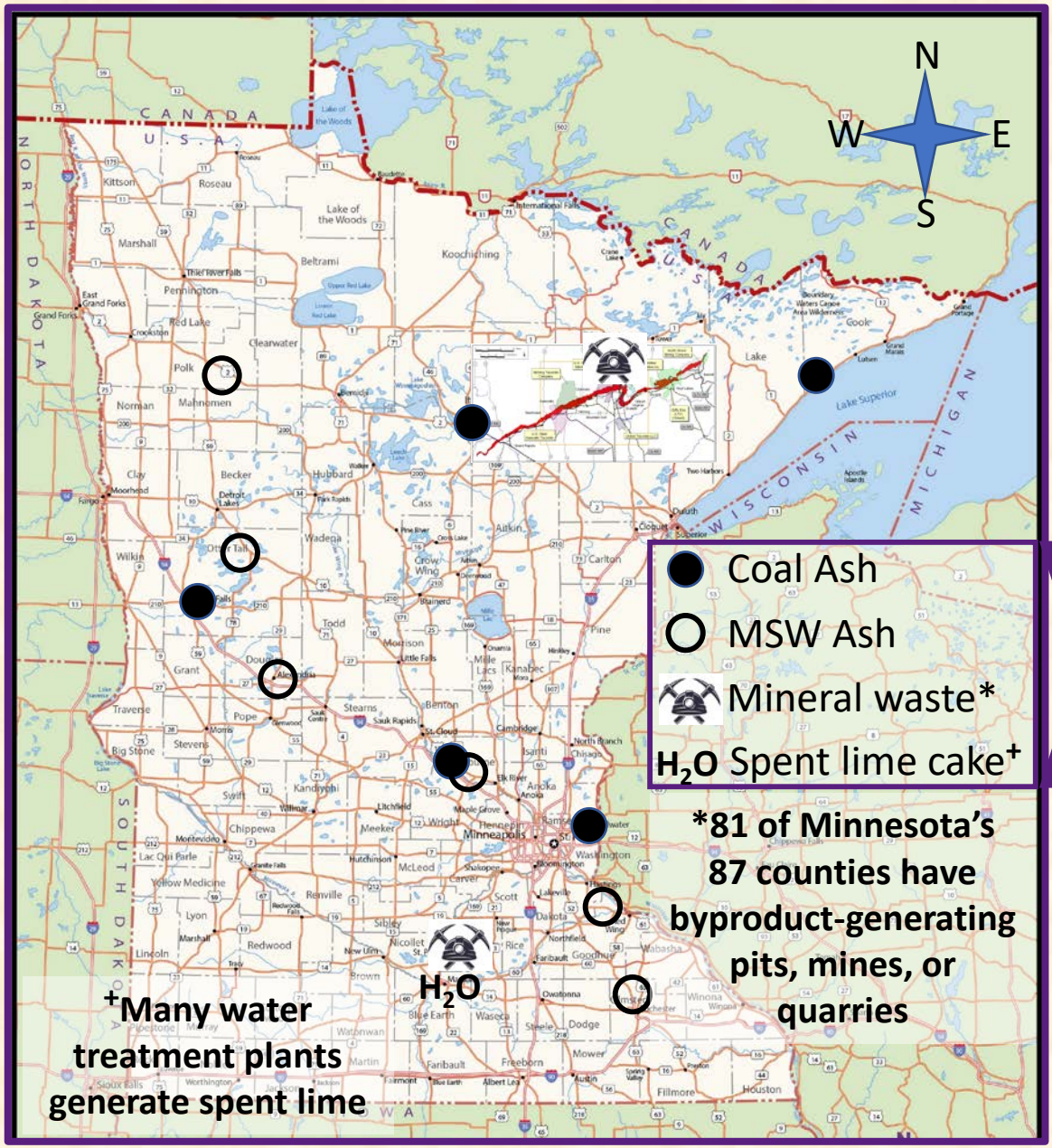
Does the organization have a fiscal agent for this project?

No

A Novel CO_2-Reducing Cement Made from Minnesota Wastes

Benefits – reduces impacts on:

- Land
- Water
- Energy
- CO_2 emissions (atmosphere)
- Non renewable Materials and Resources




Ash


Mineral fines


Lime cake

Produce an environmentally beneficial novel cement made from Minnesota industrial wastes that lessens impacts on water quality, eases pressure on landfills, and creates positive economic value while reducing CO_2 release.