Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-376

Proposal Title: Novel Ethanol Production for Ethanol Fuel Cell

Project Manager Information

Name: Sam Toan

Organization: U of MN - Duluth

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Project Basic Information

Project Summary: To mitigate greenhouse gas emissions and promote green fuel initiative in Minnesota, we propose an ethanol production pathway using CO_2 as the feedstock to prioritize ethanol Fuel Cell technology

ENRTF Funds Requested: $257,000

Proposed Project Completion: June 30, 2028

LCCMR Funding Category: Small Projects (G)

Secondary Category: Energy (E)

Project Location

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

Region(s): NE

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

Statewide

When will the work impact occur?

In the Future

Narrative

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

The proposed research seeks to address the urgent problem of rising carbon dioxide (CO_2) emissions, a major contributor to global warming and climate change. The continued reliance on fossil fuels leads to significant CO_2 emissions, exacerbating environmental degradation. Traditional methods of reducing these emissions are often costly and inefficient. Direct air capture (DAC) offers a promising new approach, but current methods have limitations in terms of CO_2 absorption efficiency, stability, and energy consumption.

This proposal aims to improve DAC technologies by utilizing activated carbon, particularly in the cold temperatures of Minnesota, to enhance CO_2 absorption efficiency. Additionally, the research focuses on the electrochemical conversion of captured CO_2 into valuable green fuels, such as ethanol, using a copper-iodide-based absorbent and low-voltage water electrolysis powered by solar energy. By achieving high conversion rates and reducing energy consumption, the project addresses the problem of energy-intensive DAC processes while offering a sustainable solution for CO_2 reduction.

Ultimately, this research presents an opportunity to not only mitigate climate change but also advance green fuel production technologies, supporting global sustainability and environmental well-being. It offers the potential to influence scientific, industrial, and policy developments toward greener energy sources and more effective climate solutions.

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

The proposed solution focuses on developing a more efficient and sustainable method for capturing and converting CO_2 into green fuels. The research aims to enhance direct air capture (DAC) technologies by utilizing activated carbon, particularly in the cold temperatures of Minnesota, to improve CO_2 absorption efficiency. Activated carbon's superior properties in CO_2 capture will be optimized for better performance in this unique climate.

The project involves creating a copper-iodide-based DAC absorbent, combined with solar-powered, low-voltage water electrolysis, to electrochemically convert captured CO_2 into ethanol. This process will achieve high conversion rates while minimizing energy consumption.

The goal is to advance DAC technology by improving CO_2 absorption, stability, and conversion rates, while reducing operational energy. This work not only offers a more efficient way to capture CO_2 but also contributes to sustainable fuel production, helping to mitigate climate change.

Funding will support the development and optimization of this technology, aiming to create a scalable solution for converting CO_2 into valuable green fuels. This approach could revolutionize CO_2 reduction efforts, support green energy development, and provide an environmentally sustainable alternative to traditional fossil fuels.

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?

As a clean energy, ethanol is considered to be one of the best replacements for fossil fuels and can be used as the energy source for the ethanol fuel cell green technology. Minnesota is one of the pioneering states in the United States to promote the application of E10, E15, and E85 ethanol-gasoline blends and has successfully used it for more than 40 years. Removal of CO_2 from industrial sources or the atmosphere, together with cutbacks in fossil fuel use, effectively relieves the dual pressures on Minnesota's environment and resources.

Activities and Milestones

Activity 1: Develop an activated carbon-based absorption and recovery system.

Activity Budget: $42,627

Activity Description:
Develop an activated carbon-based absorption system that requires a minimum flow of air (35 ml/second at lower ambient temperature ranging from -25oC to 10oC) which requires no energy apparently except that earned from the Sun during the daytime. This operation will be maximum in efficiency during wintertime in Minnesota (November to February)-best operation, March, April, September and October (moderate efficiency of capturing) and May to August (minimum efficiency of capturing). All capturing would be running during nighttime, while daytime would be for recovery and conversion.

Activity Milestones:

Description	Approximate Completion Date
Prepare activated carbon from waste-based biomass.	October 31, 2026
Prepare and evaluate the efficiency of the absorption bed	October 31, 2026
Establish a continous absorption and desoprtion process of CO2	October 31, 2026

Activity 2: Design a concentrated solar simulator

Activity Budget: $45,127

Activity Description:
A concentrated solar simulator could be used for activated carbon and/or biochar production from biomass conversion.

Activity Milestones:

Description	Approximate Completion Date
Develop a solar simulator for the pyrolysis process for activated carbon production.	February 28, 2027
Develop a linked system for CO2 desorption process.	February 28, 2027
Develop a system for the water electrolysis and CO2 reduction process	February 28, 2027

Activity 3: Develop a copper-iodide-based catalyst system

Activity Budget: $45,126

Activity Description:
Develop a copper-iodide-based catalyst which will give a photo-electrochemical process during the daytime of the conversion. The minimum power should be collected from solar energy while copper should play the role while presence of iodide would help to reduce the power consumption using direct sunlight.

Activity Milestones:

Description	Approximate Completion Date
Develop a catalyst system using copper and iodine for the reduction reaction	June 30, 2027
Configure a conbined cell for water electrolysis and CO2 reduction	June 30, 2027
Optimize the efficiency of the electrochemical reactions.	June 30, 2027

Activity 4: Develop a mechanism for controlled water electrolysis systems

Activity Budget: $45,126

Activity Description:
The conversion should be well controlled by the mechanism of controlled electrolysis of water where the supply of H+ and OH- to the conversion chamber would be selective based on the production of ethanol. The design of the water electrolysis process will play a crucial role in tailoring the selective conversion. A continuous flow of H+ or OH- will be ensured. The electrochemical cell, its features, configuration and chamber of the cell will be redesigned. It is also possible to get H2/O2 gas as a byproduct of the process as green fuel. Promote electrochemical activation of CO_2 and accelerate the reaction at the electrochemical interface through process modeling and optimization.

Activity Milestones:

Description	Approximate Completion Date
Develop cells for controlled water electrolysis	October 31, 2027
Develop a cationic and anionic selective migration system for CO2 reduction process.	October 31, 2027
Analyze and optimize the ioninc flow to the reduction cell	October 31, 2027

Activity 5: Develop an electrochemical reduction system of CO2 linked with H2O electrolysis systems

Activity Budget: $45,126

Activity Description:
Promote electrochemical activation of CO2 and accelerate the reaction at the electrochemical interface through process modeling and optimization.

Activity Milestones:

Description	Approximate Completion Date
Design and produce ethanol or propanol or butanol as required	February 28, 2028
Carry out GC-MS analysis and NMR for product qualification and quantification	February 28, 2028
Summarize interfacial reaction results and discuss the mechanism.	February 28, 2028

Activity 6: Complete a preliminary cradle-to-gate life cycle assessment (LCA).

Activity Budget: $33,868

Activity Description:
Complete a preliminary cradle-to-gate life cycle assessment (LCA) to determine whether ethanol production using the new DAC technology has potentially fewer environmental impacts than traditional methods. This will include the collection of primary life cycle inventory (LCI) data from the proposed laboratory studies and secondary LCI data for background processes such as transportation and electricity generation. The LCA models will include raw materials and energy use; emissions to air, soil, and water; transportation; and ethanol production.

Activity Milestones:

Description	Approximate Completion Date
Complete a preliminary cradle-to-gate life cycle assessment (LCA)	June 30, 2028
Complete the calculation for the inventory from raw materials to final product	June 30, 2028
Complete the LCA analysis and find the flaws of the system to refine.	June 30, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Ping Zhao	University of Minnesota Duluth	Co-PI	Yes
Matthew Aro	University of Minnesota Duluth	Co-PI	Yes

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 work be funded?

The work related to the production of ethanol by the catalytic hydrogenation of CO_2 has received worldwide attention, and it is an effective way to relieve the dual pressures on the environment and resources in Minnesota. If the proposed work is successful, we believe that to advance the technology to commercialization, our work can receive strong financial support from governmental agencies (such as the U.S. Department of Energy) and commercial enterprises. The proposed project also has gained support from collaborators, including Dr. Ping Zhao, Mr. Matthew Aro from UMD, 4H2, Inc industrial partner and White Earth Tribal Community College.

Project Manager and Organization Qualifications

Project Manager Name: Sam Toan

Job Title: Associate Professor

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

Dr. Sam Toan, Principal Investigator (PI), is an Associate Professor of Chemical Engineering at UMD. He has a strong background in materials chemistry, electrochemistry, chemical process, and catalysis studies, particularly in CO2 capture and conversion catalysis work. His work has been published in more than 50 high-quality journals such as Nano Energy and Nature Communications. In addition, he developed several complex chemical process systems to capture CO2 from variety concentration feedstocks, and convert biomass/CO2 to fuel/syngas and various value-added chemical products.

Organization: U of MN - Duluth

Organization Description:

The University of Minnesota Duluth (UMD) is a public, comprehensive regional university that is part of the University of Minnesota System. Offering 16 bachelor's degrees in 87 majors and graduate programs in 24 fields, UMD faculty, staff, and students work together to produce high-quality research that benefits people in Minnesota and beyond. The main research areas targeted by UMD and its Natural Resources Research Institute (NRRI) include ecology and natural resource management, renewable energy, advanced materials and chemistry, minerals and metallurgy, and bioeconomy development. UMD and NRRI collaborate broadly across the University system, the state and the region to address the challenges of a natural resource-based economy. By partnering with industry, business leaders, agency decision-makers and many others, UMD and NRRI researchers frame and deliver on real-world solutions. In the proposed research, the team will access UMD's chemistry and chemical engineering research expertise in CO2 capture and characterization, advanced analytical equipment in UMD's Research Instrumentation Laboratory, and NRRI's expertise and software for life cycle assessment (LCA) modeling.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sam Toan		PI/ – Project leader, responsible for overseeing CO2 capture, DAC material synthesis, and electrochemical conversion processes.			27%	0.22		$39,726
Matthew Aro		Co-PI/– Leads the life cycle assessment (LCA) of the process, evaluating environmental and economic feasibility.			27%	0.2		$23,348
Postdoc		Postdoc/work under the supervision of the PI to meet the project's goals and ensure timely completion.			21%	1.2		$93,554
Undergraduate RA		Undergraduate RA/ Assisting PI and Postdoc to work on Activity 1 to 5			0%	0.92		$29,909
Ping Zhao		Co-I/Contributes expertise in electrochemical system optimization, ensuring efficient integration of water electrolysis and CO2 conversion.			27%	0.2		$39,722
							Sub Total	**$226,259**
Contracts and Services								
UMD Instrumentation lab	Internal services or fees (uncommon)	Material characterization fees for characterize the catalyst materials such as SEM, TGA, TEM, XRD, etc.				0		$10,000
							Sub Total	**$10,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab supplies and Chemicals	consumable lab supplies and chemicals will be used to operate the proposed project					$10,221
							Sub Total	**$10,221**
Capital Expenditures								
							Sub Total	-

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Software	$230/month for each month of the entire project for hosting the SimaPro LCA software on a UMD ITSS virtual server. The fee covers server hosting, maintenance, and security.					$5,520
		Software	SimaPro LCA software service package upgrade					$5,000
							Sub Total	**$10,520**
							Grand Total	**$257,000**

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	UMN unrecovered indirect costs are calculated at the UMN negotiated rate for research of 54% modified total direct costs.	Indirect costs are those costs incurred for common or joint objectives that cannot be readily identified with a specific sponsored program or institutional activity. Examples include utilities, building maintenance, clerical salaries, and general supplies. (https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs)	Secured	$138,780
			Non State Sub Total	**$138,780**
			Funds Total	**$138,780**

Total Project Cost: $395,780

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: a05d312b-305.pdf

Alternate Text for Visual Component

CO2 emissions from industrial sources and transport vehicles in Minnesota will be efficiently captured and converted to ethanol and other useful products to help Minnesota reach its greenhouse gas emission (GHG) targets and reduce GHG's negative impacts on the climate and promote green fuel technology, ethanol fuel cell....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
UMN Authorization Letter	7a0463a7-db7.pdf
Supporting letter from WETCC	ff380d7e-6b3.pdf
Supporting letter from 4H2 inc	a03f397d-716.jpe

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

N/A

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care,

treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Sam Toan, University of Minnesota Duluth

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A