Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-434

Proposal Title: Industrial Wastewater Upcycling for Nutrient Recovery and Reuse

Project Manager Information

Name: Juan Medina Bielski

Organization: Rahr Technical Center, LLC

Office Telephone: (612) 240-0516

Email: jmedina@rahrbsg.com

Project Basic Information

Project Summary: Treatment of wastewater using innovative technologies to recover and generate nutrients for valuable agricultural byproducts, while producing cleaner effluent for process reuse and reducing reliance on well water.

ENRTF Funds Requested: $300,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Small Projects (G)

Secondary Category: Water (B)

Project Location

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

Statewide

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

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

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

Rahr Malting's Shakopee facility treats 2 million gallons of wastewater daily, discharged to the Minnesota River. While important parameters like BOD, COD, and phosphate meet regulatory standards, the treated water still carries approximately 1.5 metric tons per day of potassium (exceeding 200 ppm). Although potassium is not currently regulated and its ecological effects on aquatic systems remains poorly understood, this dissolved mineral represents a significant resource recovery opportunity. If potassium can be sequestered from the wastewater stream, it could enable partial water reuse within malting operations, reducing both groundwater withdrawals and industrial discharge to the Minnesota River.

At the same time, recovered potassium could be concentrated into a nutrient-rich brine and combined with nitrogen and retained phosphate to produce a customized, low carbon footprint N-P-K fertilizer suitable for local agricultural use. This approach transforms a waste stream into a valuable input, creating a localized circular economy and model for industrial sustainability. Additionally, sulfate discharge to surface waters is an increasing concern for many industries in Minnesota due to potential impacts on wild rice waters, which are protected under state water-quality standards. The proposed process could provide a more energy-efficient alternative to reverse osmosis, the leading process for similar pollutant.

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 opportunity will be realized through the development of a novel process integrating cutting-edge, innovative electric energy-based technologies for wastewater upcycling. This approach leverages advanced chemical solutions to recover valuable resources from industrial discharge. The work will proceed through laboratory- and pilot-scale experiments to validate the concept, optimize the process, and demonstrate scalability. Core technologies for this process include:

- Membrane Capacitive Deionization (MCDI): Sequester ions from the treated effluent to produce a concentrated potassium-rich brine. Additionally, other major components of this brine will include calcium and sulfate.
- Catalytic Nitrogen Fixation via Concentrated High-Intensity Electric Field (CHIEF)-Generated Non-Thermal Plasma (NTP): Load inorganic nitrogen species into the recovered brine, enabling N-P-K fertilizer synthesis.
- Electrohydrodynamic Evaporation (EHE): Ultra-concentrate or crystallize the nutrient stream for final formulation and transport.

Additional process optimization could be achieved through several complementary steps:

- Activated carbon filtration prior to MCDI would remove organic compounds, protecting membranes and extending operational life;
- Sonication and centrifugation would facilitate the separation of calcium and sulfate precipitates, recovering solids and mitigating scaling risks; and
- Reverse osmosis would super-concentrate the nutrient brine before electrohydrodynamic evaporation, reducing the energy intensity of the final concentration or crystallization step.

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?

Success will demonstrate an innovative process delivering three environmental benefits:

- Water Conservation: 90% clean water recovery enables industrial reuse, reducing aquifer draw and surface water discharge.
- Nutrient Reduction: Recovering 160 mg potassium and 8 mg phosphate per liter substantially reduces loading to the Minnesota River.
- Carbon Reduction: Nitrogen fixation at <40 MJ/mol produces localized fertilizer, displacing energy-intensive synthetic alternatives and reducing transport emissions.

These outcomes advance protection and enhancement of Minnesota's natural resources by transforming waste into resource, reducing water demand, mitigating nutrient pollution, and supporting sustainable agriculture.

Activities and Milestones

Activity 1: Laboratory Investigation of Nutrient Sequestration and Fixation Processes

Activity Budget: $81,000

Activity Description:
Laboratory-scale trials will first evaluate the individual performance of the core technologies, Membrane Capacitive Deionization (MCDI) and Concentrated High-Intensity Electric Field (CHIEF)-Generated Non-Thermal Plasma (NTP), in treating the effluent. These initial experiments will establish baseline performance metrics and optimize operating parameters for each technology independently.
Subsequent testing will integrate MCDI and CHIEF into a sequential process to produce a nutrient-rich solution. In this configuration, MCDI will first sequester ions from the wastewater, generating a concentrated brine. CHIEF will then fix inorganic nitrogen directly into this recovered brine, completing the N-P-K nutrient profile.
Throughout all trials, both the clean water stream and the nutrient solution will undergo comprehensive chemical characterization. Mass balance calculations will track the fate of key constituents from the initial wastewater through each process step, ensuring a complete understanding of nutrient recovery efficiency and potential losses.
Additionally, a separate set of experiments will apply CHIEF treatment to the recovered clean water stream. These trials will assess whether plasma exposure imparts any beneficial properties—such as reduced microbial load or enhanced stability—that could further enable water reuse within malting operations.

Activity Milestones:

Description	Approximate Completion Date
Chemical characterization of untreated effluent	August 31, 2027
Individual testing of MCDI + CHIEF processes	October 31, 2027
Testing of combined MCDI + CHIEF processes to produce nutrient solution	December 31, 2027
Chemical characterization of clean water and nutrient solutions	January 31, 2028

Activity 2: Laboratory-scale process improvement and optimization

Activity Budget: $154,000

Activity Description:
Following proof-of-concept for nutrient solution production via integrated MCDI and CHIEF treatment, this activity will address scaling obstacles through systematic optimization.
Hardness Management: Calcium and other hardness ions as well as sulfate, an anion of environmental and agricultural concern, will concentrate alongside potassium in the MCDI brine. These minerals add no agricultural value and promote scaling. Targeted hardness reduction strategies will be investigated to improve product stability and usability.
Nutrient Concentration: To enable economic storage and transport, the nutrient solution will be further concentrated via two complementary approaches:

- Membrane Filtration: Reverse osmosis and related technologies
- Evaporation Technology: Electrohydrodynamic evaporation (EHE) for ultra-concentration or full dehydration

Resulting product options—from concentrated brine to dehydrated solids—will be compared. Brine offers simplicity for on-farm dosing; solids eliminate water weight for maximum transport economy.
Comparative Evaluation: All formulations will undergo:

- Chemical characterization
- Stability testing
- Application testing (mixing, dosing, equipment compatibility)

- Energy accounting

This optimization will yield a technically and economically viable product ready for pilot-scale validation.

Activity Milestones:

Description	Approximate Completion Date
Hardness reduction/calcium removal processes development	May 31, 2028
Chemical characterization of calcium and sulfate removal products	June 30, 2028
Nutrient concentration and densification process development via RO, EHE, or related technologies	December 31, 2028
Chemical characterization of final concentrated/densified nutrient product	January 31, 2029
Nutrient solution stability and application testing	February 28, 2029

Activity 3: Evaluation of Scalability and Economic Feasibility

Activity Budget: $65,000

Activity Description:

This activity will assess the scalability and economic viability through integrated technical and market analysis.

Mass and Energy Balance: Complete balances for the optimized process will establish resource requirements and efficiency metrics needed to project commercial-scale performance.

Comparative Benchmarking: The process will be benchmarked against current practices and imported potash across three dimensions:

- Carbon footprint: Lifecycle emissions versus conventional fertilizer production and transport
- Water use: Net consumption compared to status quo discharge
- Economic competitiveness: Projected market positioning of recovered minerals

Economic Impact Assessment: Analysis will quantify net benefits versus the status quo, including avoided water pumping and treatment costs, revenue from recovered nutrients, and economics of on-site water reuse.

Pilot Malting Trials: Recovered water—with and without CHIEF treatment—will be evaluated for malting performance. Trials will assess germination rates, enzyme activity, and finished product quality to determine whether upcycled water offers processing benefits.

Together, these analyses will establish the technical scalability, economic viability, and market potential of the integrated nutrient recovery and water reuse system.

Activity Milestones:

Description	Approximate Completion Date
Pilot Malting trial	March 31, 2029
Process energy and mass balance analysis	April 30, 2029
Economic analysis of optimized process	April 30, 2029
Final comprehensive report issued	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Trevor Cowley	RahrBSG	Co-PI	Yes
Roger Ruan	University of Minnesota	Co-PI	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
Following project completion, Rahr will serve as a flagship demonstration site, enabling replication at other industrial water treatment facilities. The team will disseminate findings through industry partnerships as well as in industry and academic publications and by presentations at industry and academic conferences. Nutrient byproducts will undergo rigorous validation to establish agronomic value, supporting market development with local agricultural cooperatives and creating pathways for off-take agreements.

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?
Project findings will be shared with Minnesota regulatory agencies, industrial water users, agricultural stakeholders, and technical audiences to ensure the results can be applied to water reuse, nutrient recovery, and wastewater management in Minnesota. A final technical report will summarize nutrient recovery efficiency, water reuse performance, product stability, mass and energy balances, and economic benchmarks. That report and shorter technical summaries will be shared with the MPCA programs responsible for industrial discharge and water permitting, and with the MDA because of the project's fertilizer-recovery component. Dissemination will also focus on potential adopters. Results will be shared directly with industrial wastewater managers,

Project Manager and Organization Qualifications

Project Manager Name: Juan Medina Bielski

Job Title: Scientist

Provide description of the project manager's qualifications to manage the proposed project.
Research and innovation scientist with extensive experience in design of experiments, managing multiple projects, data analysis and reporting, pilot plant operations management, and technology scale-up. Research has often focused on process-resource management, including energy efficiency, water efficiency, and wastewater upcycling.

Organization: Rahr Technical Center, LLC

Organization Description:
The Rahr Technical Center, LLC is the research unit that conducts laboratory research, innovation and new product development work, and quality initiatives serving RahrBSG (Rahr Corporation), and this includes work to improve environmental sustainability. RahrBSG manufactures and supplies ingredients to the brewing industry. The core of the business is malting, wherein Rahr Malting is the top producer in North America, with North America's largest production facility located in Shakopee, MN. Malting is an agricultural processing activity, converting small grains, primarily barley, into malt, the principle ingredient in beer apart from water. The malting facilities in Shakopee are powered by Koda

Energy (under the Rahr corporate umbrella) which generates 24 megawatts of fossil-fuel-free electricity through biomass gasification. Rahr Malting also treats around 2 million gallons per day of process water to meet water quality standards for discharge.

Note: Rahr Technical Center, LLC is a disregarded entity under Rahr Corporation.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager / Research Scientist		Project Manager will lead all experimental design, laboratory testing, and process integration across Activities 1–3. Responsibilities include operation and optimization of MCDI, CHIEF, and EHE systems, chemical characterization, mass and energy balance development, and coordination of project activities and reporting.			10%	2		$250,000
Co-PI / Technical Lead (Industry)		Co-PI will provide technical oversight, support experimental design and data interpretation, and guide evaluation of process applicability within malting operations. Responsibilities include review of results, process integration considerations, and contribution to scalability and economic analysis (Activity 3).			10%	0.1		$8,000
							Sub Total	**$258,000**
Contracts and Services								
University of Minnesota Research Analytical Laboratory	Service Contract	Specialized analytical services including ICP-MS for elemental analysis and nutrient quantification across process stages. Analyses support mass balance verification, nutrient recovery efficiency assessment, and characterization of concentrated brine and final products.				0.06		$5,000
University of Minnesota	Subaward	Provides technical advisory services on process design, experimental planning, and data interpretation. Includes consultation on system integration, performance evaluation, and scalability.				0.1		$8,000
							Sub Total	**$13,000**
Equipment, Tools, and Supplies								
	Equipment	Customized, modular electrohydrodynamic evaporation (EHE) system components for bench-scale nutrient concentration testing. Components	One of the key pieces of novel technology comprising the innovative					$20,000

		include: High-voltage power supply modules (2 × $4,000 = $8,000); Emitter and electrode assemblies (2 × $2,500 = $5,000); Flow control and distribution systems (2 × $2,000 = $4,000); Control electronics and monitoring sensors ($3,000). These components enable controlled evaporation, concentration, and crystallization of nutrient streams under laboratory conditions.	process - Electrohydrodynamic Evaporation (EHE) system					
	Equipment	Bench-scale reverse osmosis system for brine pre-concentration and evaluation of membrane-based nutrient densification prior to EHE treatment.	RO system used for process optimization for brine concentration and anti-fouling					$2,000
	Equipment	Ultrasound apparatus to support hardness removal experiments, including calcium precipitation and mitigation of scaling during concentration processes.	Ultrasound system used for process optimization (hardness removal via precipitation)					$1,000
	Tools and Supplies	Personal protective equipment (gloves, eye protection) to ensure safe laboratory operation.	PPE					$300
	Tools and Supplies	Consumables required for process development and testing, including chemicals, reagents, membranes, filter media, and operational materials. Supports nutrient sequestration, nitrogen fixation, and concentration experiments across all project activities.	Consumables and Lab Supplies					$5,700
							Sub Total	**$29,000**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**

Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

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				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $300,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 06a34013-c3c.pdf

Alternate Text for Visual Component

The graphic is a visual depiction of the proposed process flow, showing the key steps and inputs and outputs....

Financial Capacity

Title	File
Financial Capacity Note	a8e83533-8f2.pdf

Supplemental Attachments

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

Title	File
Board Resolution Letter	5b8c6cd8-570.pdf

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?

No

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

N/A

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

N/A

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:

Juan Medina Bielski, Trevor Cowley, Juer Liu, Roger Ruan, Mike Abramson, Kevin Sandoval, John Van Rensburg

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

Yes, I understand