



# Environment and Natural Resources Trust Fund

2027 Request for Proposal

## General Information

**Proposal ID:** 2027-200

**Proposal Title:** Low Impact Water Energy Harvesting for Renewable Energy

## Project Manager Information

**Name:** Ping Zhao

**Organization:** U of MN - Duluth

**Office Telephone:** (218) 726-8802

**Email:** zhaop@d.umn.edu

## Project Basic Information

**Project Summary:** This project advances low-impact renewable energy generation from water motion, developing small-scale systems that produce electricity and expand clean energy options while protecting Minnesota's freshwater ecosystems.

**ENRTF Funds Requested:** \$454,000

**Proposed Project Completion:** June 30, 2030

**LCCMR Funding Category:** Energy (E)

## 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.**

Minnesota's rivers, streams, and urban waterways are essential natural resources that support communities, aquatic ecosystems, recreation, and economic activity. As the state continues transitioning toward cleaner energy systems, there is growing interest in distributed renewable energy technologies that can operate reliably within natural environments without increasing ecological disturbance. Flowing water contains usable kinetic energy, yet conventional hydropower technologies are often unsuitable for small-scale or environmentally sensitive settings because they require dams, turbines, or permanent infrastructure that can alter natural flow regimes and disrupt aquatic habitats. There is a need to expand renewable electricity generation options that can function within existing waterways while maintaining hydrologic integrity and protecting ecosystem health. Mechanically simple, non-obstructive energy harvesting approaches is a potential solution, but limited validated performance data exist under conditions representative of Minnesota's freshwater systems. Without such data, it is difficult to assess feasibility, environmental compatibility, and appropriate application contexts. Addressing this gap will support informed renewable energy innovation while ensuring that development in water environments proceeds in a manner consistent with the protection and preservation of the state's natural resources.

### **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.**

This project will develop, refine, and validate a low impact approach to generating renewable electricity from naturally occurring water motion. Rather than installing permanent infrastructure that can modify waterway geomorphology and flow regimes, this work focuses on compact, portable systems that respond to water movement and convert mechanical motion into usable electrical output. Our preliminary prototype testing conducted in a controlled water flume demonstrated proof of concept, successfully producing electrical power in the milliwatt range at a representative flow velocity of 0.5 m/s. These promising results confirm technical feasibility and justify further refinement and systematic evaluation under broader operating conditions. The proposed work will expand upon this foundation through prototype optimization, controlled performance testing, and assessment of structural durability and ecological compatibility. Data-informed design strategies will be applied to improve efficiency and operational reliability while minimizing material use and unnecessary fabrication cycles. Hydrologic expertise will guide interpretation of results to ensure applicability across diverse Minnesota water settings. The project emphasizes research and validation rather than deployment. By generating credible performance data and environmental guidance, this work will inform responsible renewable energy development in water environments statewide.

### **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 project will produce validated performance data and ecological compatibility assessments for low impact water motion energy systems that operate within natural flow conditions. By evaluating renewable electricity generation while minimizing disturbance to hydrology and aquatic habitat, the work directly supports protection, conservation, and preservation of Minnesota's freshwater resources. Outcomes will inform cost-effective decisions on designing and applying environmentally responsible renewable energy development in freshwater environments. The approach also contributes to long term sustainability by reducing reliance on disposable batteries and fossil fuel based electricity commonly used in remote monitoring and distributed infrastructure applications.

## Activities and Milestones

### Activity 1: Design and Development of Low Impact Water Energy Harvesting Systems

**Activity Budget:** \$117,197

**Activity Description:**

The objective of this activity is to systematically design and develop improved low impact water energy harvesting systems that build upon preliminary proof-of-concept prototypes. Initial testing in a controlled water flume demonstrated milliwatt-scale electrical output at representative flow velocities, confirming technical feasibility. However, only a limited number of configurations have been explored, and broader design optimization is needed to improve efficiency, durability, and adaptability to varying flow conditions. This activity will expand design exploration through systematic design evaluation and modeling analysis, refinement of structural geometry, material evaluation, and fabrication of multiple prototype configurations. We will perform computational fluid dynamics modeling to guide design parameters, assess structural response to flow-induced loading, and evaluate encapsulation strategies suitable for aquatic environments. Based on the modeling results, we will go through iterations of designs focusing on increasing electrical output, improving mechanical robustness, and reducing material use while maintaining a minimal ecological footprint. Specific outputs include multiple refined prototype systems, documented engineering specifications, and baseline performance data under controlled conditions. Activity outcomes will be evaluated based on measurable improvements in energy output, structural stability, and readiness for systematic validation in Activity 2. Successful completion will establish a technically robust foundation for environmentally compatible renewable energy.

**Activity Milestones:**

Description	Approximate Completion Date
Finalize Design Criteria and Performance Targets	November 30, 2027
Complete Prototype Design Optimization	April 30, 2028
Fabricate and Assemble Refined Prototype Systems	September 30, 2028
Complete Bench Scale Electrical Output Verification	December 31, 2028

### Activity 2: Experimental Testing and Performance Evaluation

**Activity Budget:** \$168,390

**Activity Description:**

The objective of this activity is to systematically evaluate the performance, durability, and environmental compatibility of refined water energy harvesting prototypes developed in Activity 1. This phase will generate validated data necessary to assess feasibility and practical application under representative flow conditions. We will perform controlled laboratory testing in a water flume on the prototypes developed to measure electrical output, power density, and conversion efficiency across a range of flow velocities common in Minnesota waterways. We will perform repeated loading cycles to evaluate the durability and operational reliability of the prototypes. Additional analysis will examine device flow interactions to confirm minimal disturbance to surrounding hydrodynamic conditions. Testing will be accomplished using calibrated instrumentation to record voltage, power output, and flow parameters under repeatable conditions. Data will be analyzed to quantify performance trends and identify optimal operating regimes. Specific outputs include validated performance datasets, durability assessment results, and environmental interaction characterization. Outcomes will be evaluated based on reproducibility of electrical output, structural integrity, and consistency across flow conditions. These results will provide credible evidence to inform responsible renewable energy development in freshwater environments statewide.

**Activity Milestones:**

Description	Approximate Completion Date
Initiate Controlled Flow Performance Testing	February 28, 2029
Quantify Power Output Under Variable Flow Regimes	June 30, 2029
Evaluate Structural Durability Under Repeated Loading Cycles	December 31, 2029
Characterize Hydrologic Interaction and Ecological Compatibility	March 31, 2030

### Activity 3: Performance Analysis and Technical Guidance Development

**Activity Budget:** \$168,413

**Activity Description:**

The objective of this activity is to analyze experimental results, refine system performance, and develop technical guidance to inform responsible renewable energy applications in freshwater environments. Building upon validated testing data from Activity 2, this phase will synthesize findings to identify optimal design configurations, performance thresholds, and operational parameters. We will perform analysis of electrical output, efficiency trends, durability under cyclic loading, and flow interaction behavior. The analysis will quantify performance variation across flow conditions and identify key factors influencing energy generation and structural stability. Design parameters will be optimized to improve conversion efficiency and reliability while maintaining minimal ecological disturbance. Specific outputs include optimized performance parameters, comparative evaluation of prototype configurations, and preparation of a final technical report summarizing findings, environmental considerations, and recommended operating ranges. A stakeholder oriented summary will also be prepared to communicate key insights to agencies and water resource planners. Activity outcomes will be evaluated based on demonstrated performance improvements, consistency across test conditions, and completion of final deliverables. This activity ensures that the project produces actionable, evidence-based guidance to support environmentally compatible renewable energy development in Minnesota.

**Activity Milestones:**

Description	Approximate Completion Date
Complete Performance Data Analysis	December 31, 2029
Finalize Optimized System Design Parameters	February 28, 2030
Prepare Technical Guidance and Stakeholder Summary	May 31, 2030
Submit Final Technical Report and Deliverables	June 30, 2030

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Kun Zhang	University of Minnesota Duluth	Dr. Zhang will provide expertise in hydrologic processes, urban water systems, and climate stressors to interpret system performance under representative Minnesota conditions. He will advise on flow regimes and seasonal variability and support data analytics to ensure results reflect real-world hydrologic context and resilience considerations.	Yes
Sam Toan	University of Minnesota Duluth	Dr. Toan will contribute expertise in energy materials and polymer systems to enhance durability and environmental compatibility of the energy harvesting components. He will advise on material selection, encapsulation, and lifecycle considerations for aquatic operation, supporting reliable performance while maintaining appropriate project scope.	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.**

Project results will be disseminated through a final technical report, open-access peer-reviewed publications, conference presentations, and stakeholder-oriented summaries. Findings will be shared with Minnesota state agencies, watershed organizations, and water resource managers to support informed decision-making related to environmentally compatible renewable energy in freshwater systems. A stakeholder summary will translate technical results into accessible language to encourage practical application and environmentally responsible energy development. Project data and documentation will be maintained in accordance with university policies to ensure long-term accessibility. All publications, presentations, and materials will acknowledge support from the Environment and Natural Resources Trust Fund in accordance with ENRTF Acknowledgment Guidelines. Dissemination-related costs, including open-access publication fees, are included in the project Activities and Budget.

## 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 disseminated through detailed technical reports, stakeholder summaries, and presentations to state agencies, watershed organizations, and other entities engaged in renewable energy and water resource planning. The results will provide practical guidance regarding performance expectations, environmental considerations, and potential application contexts for low impact water motion energy systems. The project is structured as research and validation rather than infrastructure deployment. Any future pilot studies, field demonstrations, or application-specific integration would be pursued through separate competitive funding sources, including state or federal research programs and partnerships with public agencies. No additional ENRTF support is anticipated beyond the proposed

## Project Manager and Organization Qualifications

**Project Manager Name:** Ping Zhao

**Job Title:** Associate Professor

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

Dr. Ping Zhao is an Associate Professor in Mechanical and Industrial Engineering at the University of Minnesota Duluth with expertise in renewable energy systems. Her research focuses on developing and experimentally validating small-

scale approaches that convert mechanical motion into electrical energy for sensing, monitoring, and resilient infrastructure applications. Dr. Zhao has extensive experience leading multidisciplinary research projects involving device design, fabrication, laboratory testing, and performance evaluation. She has successfully supervised graduate and undergraduate research teams, and coordinated collaborative efforts across engineering disciplines. Located in northeastern Minnesota near major freshwater systems, Dr. Zhao's research emphasizes renewable energy solutions that operate within natural environments without altering hydrology or disrupting ecological processes. As Project Manager, she will oversee technical execution, budget management, reporting, and team coordination. Her established record in renewable energy research and project leadership ensures the proposed work will be executed effectively and aligned with the public purpose of protecting and enhancing Minnesota's natural resources.

**Organization:** U of MN - Duluth

**Organization Description:**

The University of Minnesota Duluth (UMD) is a public research university within the University of Minnesota System committed to advancing research, education, and service that benefit Minnesota's communities and natural resources. UMD integrates applied research and public engagement to address challenges in renewable energy, water resources, and sustainable infrastructure. This proposal is led through the Swenson College of Science and Engineering and involves collaboration among the Departments of Mechanical and Industrial Engineering, Civil and Environmental Engineering, and Chemical Engineering. These departments conduct research in renewable energy systems, hydrology and water resources, and materials engineering, supporting environmentally compatible technologies relevant to Minnesota's rivers, streams, and urban water infrastructure. Located along Lake Superior, UMD provides direct access to diverse freshwater systems and offers the facilities, interdisciplinary expertise, and administrative support necessary to successfully manage externally funded research in alignment with state requirements.

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Dr. Ping Zhao, PI		Dr. Zhao will serve as the Project Manager and lead all aspects of the project. She will be responsible for overall project coordination, technical direction, and communication with the LCCMR. Dr. Zhao will lead the design, fabrication, and evaluation of low impact water energy harvesting systems; oversee laboratory and field-relevant testing; integrate data-informed design approaches; and synthesize project results into decision-useful outcomes.			26.8%	0.24		\$46,672
Dr. Kun Zhang, Co-I		Dr. Zhang will provide expertise in hydrologic processes, urban water systems, and climate stressors to interpret system performance under representative Minnesota conditions. He will advise on flow regimes and seasonal variability and support data analytics to ensure results reflect real-world hydrologic context and resilience considerations.			26.8%	0.24		\$38,024
Dr. Sam Toan, Co-I		Dr. Toan will contribute expertise in energy materials and polymer systems to enhance durability and environmental compatibility of the energy harvesting components. He will advise on material selection, encapsulation, and lifecycle considerations for aquatic operation, supporting reliable performance while maintaining appropriate project scope.			26.8%	0.24		\$43,831
Master's Graduate Research Assistant		The graduate research assistant will support prototype development, experimental testing, data collection, and performance analysis. Responsibilities include conducting flow experiments, evaluating durability, processing electrical measurements, and assisting with preparation of technical reports and project documentation. The % benefits calculation includes 3 semesters of tuition remission at \$9,360 each.			50.5%	0.57		\$72,907
Postdoctoral associate		The postdoctoral associate will lead prototype refinement, experimental design, and performance evaluation. Responsibilities include supervising laboratory testing, analyzing performance and			20.7%	2.49		\$199,321

		durability data, coordinating with collaborators, preparing technical reports, assisting with proposals for follow-on funding, and ensuring timely completion of project milestones and deliverables						
							<b>Sub Total</b>	<b>\$400,755</b>
<b>Contracts and Services</b>								
							<b>Sub Total</b>	<b>-</b>
<b>Equipment, Tools, and Supplies</b>								
	Equipment	Waterproof sensors	Waterproof sensors are required to measure pressure and displacement of the energy harvesting devices during submerged testing. These measurements are essential to quantify mechanical response under representative flow conditions and correlate structural behavior with electrical performance.					\$3,000
	Equipment	Computer work station	The requested computer workstation is necessary to perform computational fluid dynamics (CFD) modeling to simulate flow structure interactions and guide prototype refinement.	X				\$5,000
	Tools and Supplies	Raw materials and supplies	Raw materials and supplies, such as epoxy, wiring, plastic sheets, and 3D printing filaments and resins, etc., are required for fabrication and refinement of prototype water energy harvesting systems. These materials will be used exclusively for constructing, assembling, and testing device configurations under controlled flow conditions as part of the proposed research activities.					\$7,589
							<b>Sub Total</b>	<b>\$15,589</b>
<b>Capital Equipment</b>								

		Shaker system	The shaker system is necessary to simulate controlled vibration and dynamic loading conditions representative of water-induced motion in a laboratory environment. It will be used to apply adjustable frequency and amplitude inputs to energy harvesting prototypes, enabling systematic evaluation of electrical output, structural response, and durability under repeatable conditions. The resulting data will directly support prototype refinement, performance validation, and environmental compatibility assessment outlined in Activities 1 and 2.	X				\$15,000
							<b>Sub Total</b>	<b>\$15,000</b>
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
							<b>Sub Total</b>	-
<b>Travel Outside Minnesota</b>								
	Conference Registration Miles/ Meals/ Lodging	Six conference trips (three PIs attending one conference annually in Years 2 and 3). Each trip includes round-trip airfare, three nights lodging, registration fees, and per diem at standard institutional travel rates.	To disseminate validated project findings at national renewable energy conferences where technical sessions directly align with low impact water motion energy systems. Out of state travel is necessary to present results, engage with experts in specialized energy harvesting research, and obtain technical feedback relevant to project objectives.	X				\$13,656
							<b>Sub Total</b>	<b>\$13,656</b>

<b>Printing and Publication</b>								
	Publication	Open-access publication fees for peer-reviewed renewable energy journal (e.g., Renewable Energy or similar)	To disseminate validated project findings on low impact water motion energy systems and ensure broad public access to results generated with ENRTF support.					\$9,000
							<b>Sub Total</b>	<b>\$9,000</b>
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$454,000</b>

## Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
<b>Equipment, Tools, and Supplies</b>		Computer work station	The workstation will be dedicated solely to this project, as the required simulations demand high computational capacity not available through shared resources.
<b>Capital Equipment</b>		Shaker system	The shaker will be dedicated to this project during the award period, and its use will be individually documented as directly related to project experiments and deliverables. <b>Additional Explanation</b> : Following project completion, the shaker system will continue to support the same renewable water-energy research program, including ongoing prototype refinement, follow-on externally funded studies, and related experimental validation within the same line of investigation.
<b>Travel Outside Minnesota</b>	Conference Registration Miles/Meals/Lodging	Six conference trips (three PIs attending one conference annually in Years 2 and 3). Each trip includes round-trip airfare, three nights lodging, registration fees, and per diem at standard institutional travel rates.	Out of state travel is requested as there are not similarly large conferences of this type available in MN. Each trip will be individually documented and directly tied to presentation of ENRTF supported results.

## Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
<b>State</b>				
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. ( <a href="https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs">https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs</a> )	Secured	\$410,919
			<b>State Sub Total</b>	<b>\$410,919</b>
<b>Non-State</b>				
			<b>Non State Sub Total</b>	-
			<b>Funds Total</b>	<b>\$410,919</b>

**Total Project Cost: \$864,919**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

#### *Visual Component*

File: [2d85a670-3ee.pdf](#)

#### *Alternate Text for Visual Component*

The visual presents a one-page overview of the proposed project, including the problem statement, proposed approach, three-phase work plan, and expected outcomes....

### Supplemental Attachments

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

Title	File
Authorization Letter	<a href="#">e11b8fd4-15e.pdf</a>

## 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?**

Yes, I understand the UMN Policy on travel applies.

**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:**

Ping Zhao, Kun Zhang, Sam Toan, Michael Jacob, Claudia Carranza

**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