Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-050

Proposal Title: Paving the Future with Biochar Modified Asphalt

Project Manager Information

Name: Lawrence Zanko

Organization: U of MN - Duluth - NRRI

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Project Basic Information

Project Summary: Use biochar produced from Minnesota biomass in modified asphalt mixes (conventional and recycled material-based) to demonstrate/quantify its greenhouse gas and noxious emission reduction, resource/energy conservation, and economic benefits.

Funds Requested: $369,000

Proposed Project Completion: June 30, 2027

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): NE

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

Region(s): NE

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.

94% of roads are paved with asphalt. Asphalt pavements are made by combining coarse and fine aggregate (small rocks and sand) and then adding about 5% petroleum-based cement as a binder. This mixture is heated from 270F to 325F in conventional, fossil fuel-burning asphalt production plants.

Biochar produced from Minnesota's waste biomass resources has properties that make it potentially suitable for use in asphalt mixes and binders to impart significant decarbonization benefits. A bibliographical review of biochar as an asphalt binder and asphalt mix modifier found: "Few studies have evaluated the performance of biochar on asphalt mixes and the long-term properties associated with durability" (Sustainability, 2022).

Therefore, asphalt mixes and specimens made with and without biochar will be tested and compared to conventional ("virgin") mixes and mixes made with significant percentages of reclaimed/recycled asphalt pavement (RAP) and microwave-absorbing byproduct materials. The proposed project will also tie into a recently available emerging industrial-scale technology – microwave-based asphalt production – shown to be environmentally superior to fossil fuel-intensive asphalt production and capable of being powered by renewable energy.

The project team will demonstrate/quantify greenhouse gas and noxious emission reduction, resource and energy conservation, and economic benefits while determining what biochar works best.

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.

We seek to:

- Produce biochar derived from Minnesota waste biomass sources
- Formulate and test biochar-based asphaltic binders and mixes
- Test conventional ("virgin") and RAP-based asphalt mix designs made with and without biochar and microwave-absorbing taconite and/or other components at the laboratory scale
- Model the heat transfer process when microwave energy is used for mixture heating
- Compare energy consumption and emission production of microwave and fossil fuel-based asphalt heating (i.e., conduct a life cycle assessment, or LCA)
- Collect and test core samples from and monitor the performance of one or more asphalt pavements, including (if available) test pavements made using biochar modified mix designs and/or RAP-based mixes produced from a microwave-based asphalt plant.

Notably, RAP used in asphalt production can take advantage of its existing binder content, but RAP binder's aged nature limits its usage to 20% to 30% of the mixture. Using biochar modified binders to increase RAP usage in RAP-based mix designs would be a highly desirable resource conservation and greenhouse gas-reducing goal. Still, conventionally heated asphalt plants consume fossil fuel and contribute to greenhouse gases and other combustion-related emissions while further aging RAP binders. Microwave-based heating combined with biochar can represent an environmentally mitigative advance.

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?

PROTECTION: Quantify greenhouse gas and other noxious emission reductions achieved using biochar produced from Minnesota waste biomass sources in asphalt production.

ENHANCEMENT and CONSERVATION: Identify optimal biochar-based asphalt formulations for conventional asphalt

mixes and mixes that maximize the use of RAP

CONSERVATION and PRESERVATION: Demonstrate the energy benefit of using microwave technology to heat microwave-absorbing byproducts and co-products generated by Minnesota’s iron ore (taconite) mining industry, in combination with reclaimed asphalt and biochar modified asphalt binders in pavement mix designs

ENHANCEMENT: Demonstrate the project's efficacy by testing the performance of biochar modified mix designs, microwaved and conventionally heated.

Activities and Milestones

Activity 1: Project kickoff/planning meetings; literature review; obtain supplies/materials; biochar production and asphalt formulation development; initial heating tests; reporting

Activity Budget: $125,000

Activity Description:
Activity 1 will lay the foundation for the project. Early Activity 1 work will include a team kickoff meeting and follow-up planning meetings for coordination of effort and milestone achievement, to be followed by selecting a UMTC graduate student and identifying the project role they will play with respect to biochar-based asphalt binder development and testing, with their initial work beginning with a literature review of the state of the science. The NRRI will focus its early efforts on identifying and selecting waste biomass resources for biochar production, while both UMTC and NRRI will obtain laboratory supplies and raw materials (aggregate, asphalt binders, RAP, biomass, etc.) needed to carry out their respective and interrelated project responsibilities. Upon completion of these foundational tasks, biochar production and asphalt binder and asphalt mix formulation work will commence, with the NRRI producing and testing the biochar UMTC will need for preparing specimens made from modified asphalt binder formulations and mix designs, to compare with "control" binders and mix designs. Conventional and microwave heating of an initial set of binders, mix designs, and specimens will take place to provide data for heat transfer modeling. Activity 1 will be summarized in a Year 1 progress report.

Activity Milestones:

Description	Approximate Completion Date
Project team kickoff and work plan strategy meetings for coordination of effort and milestone achievement	September 30, 2024
Perform literature review; obtain lab supplies and raw materials; prepare labs and define testing procedures	December 31, 2024
Biochar production; develop and test asphalt binder, mixes, and specimens; conventional vs microwave heating modeling	September 30, 2025
Team meetings throughout 2025; in-state conference attendance/participation; Activity 1 progress report to LCCMR	December 31, 2025

Activity 2: Preparation, characterization, and testing of candidate biochar and biochar modified asphalt binders, mixes, specimens, and representative pavement core samples.

Activity Budget: $150,000

Activity Description:
Activity 2 builds on Activity 1. "Best" biochar candidates will be identified. Up to 10 mixes will be tested (including non-biochar modified control mixes, RAP and virgin) and specimens prepared with conventional and microwave heating. UMTC will perform predictive laboratory tests (e.g., complex modulus, and shear and bending beam rheometer testing, for asphalt mixes and binders) to evaluate physical properties and durability under conditions applicable to Minnesota's climate. Preparation of asphalt mixture specimens using conventional and microwave heating will determine critical material parameters for modelling their respective heat transfer processes. NRRI/UMD will perform supplemental testing and characterization of UMTC specimens, and on cores from representative asphalt pavements made from virgin and RAP-based mixes. UMD will test cores to determine their resistance to low-temperature cracking and freeze-thaw cycles – the dominant causes of failure in Minnesota's asphalt pavements and potholes in the early spring. Disc-shaped compact tension (DCT) per ASTM D7313 will be conducted on the samples with and without the application of freeze-thaw cycles at a sub-zero temperature suggested for Minnesota’s condition and based on the project’s selected asphalt

binder grade. An LCA will be performed to quantify environmental/climate-related impacts/benefits of biochar formulations and conventional-vs-microwave heating methods.

Activity Milestones:

Description	Approximate Completion Date
Preparation, testing and characterization of "best" candidate biochar, binders, asphalt mixes, specimens, and core samples	September 30, 2026
Lab-based microwave heating tests and heat transfer modeling of candidate binder and mix formulations	November 30, 2026
LCA to quantify to environmental/climate-related impacts/benefits of the respective formulations and heating methods	December 31, 2026
Team meetings throughout 2026; in-state conference attendance/participation; Activity 2 progress report to LCCMR	December 31, 2026

Activity 3: Complete remaining testing; compile and summarize project findings; potentially implement formulation(s) in a demo-scale project; final report to LCCMR

Activity Budget: $94,000

Activity Description:
Remaining testing and field work will be completed, with results and findings compiled and summarized. The project team's findings will be used to demonstrate/quantify greenhouse gas and noxious emission reduction, resource and energy conservation, and economic impacts/benefits based on what biochar and biochar/asphalt combinations work best, and the heating method used. The project's findings will be assembled for peer reviewed journal article preparation as well as for conference presentation. There is also potential for the team's findings and formulations to be implemented in a field-scale paving application, a potentiality that could be facilitated by the installation of an industrial-scale microwave asphalt plant in NE Minnesota during the project period (presently under discussion). If this development goes forward, access to such a next-stage technology facility could allow the assembled research team's biochar modified asphalt findings to be tested and implemented during the project. Activity 3 and the project wraps up with a final report to LCCMR.

Activity Milestones:

Description	Approximate Completion Date
Team completes remaining lab work and summarizes project findings	March 31, 2027
Conference attendance/participation and journal article preparation to disseminate project findings	June 30, 2027
Potential use of project's biochar-based formulations in a demonstration-scale paving project.	June 30, 2027
Final project report to LCCMR	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Prof. Mihai Marasteanu	University of Minnesota Twin Cities	Co-investigator: Dr. Marasteanu's research at the University of Minnesota has focused on two main themes: application of viscoelasticity and fracture mechanics concepts to asphalt materials characterization, and the development of simple, implementable laboratory testing methods based on complex material characterization analyses. He will lead the project's asphalt formulation testing program.	Yes
Prof. Manik Barman	University of Minnesota Duluth	Co-investigator: Dr. Barman teaches infrastructure materials and pavement engineering-related courses at UMD. He conducts research on pavement materials, maintenance, and rehabilitation. He and Dr. Marasteanu will coordinate their students' field work and laboratory testing roles, and will collaborate on assessing the performance of microwaved recycled asphalt blends and formulations.	Yes
Prof. Jialiang Le	University of Minnesota Twin Cities	Co-Investigator: Dr. Liang's research interests include fracture mechanics, probabilistic mechanics, scaling, and structural reliability. Current research efforts focus on deterministic and probabilistic modeling of fracture and fatigue of brittle heterogeneous (quasibrittle) materials such as concrete, fiber composites, etc. He will lead modeling of RAP-based asphalt formulations and microwave heat transfer.	Yes
Mr. Vern Hegg	Microwave Industry Consultants, LLC	Mr. Hegg is an industrial-scale electrical and microwave heating system expert, and has designed the type of microwave-based asphalt plant from which this project will receive recycled asphalt products. He will provide the project team with energy data for quantifying the environmental impacts of microwave and conventional asphalt heating systems.	No
Bridget Ulrich, PhD	Natural Resources Research Institute (NRRI)	Dr. Ulrich is NRRI's Aqueous Geochemist. She also works closely with the Materials and Bioeconomy group to develop biochar materials for water treatment applications, with a specific interest in evaluating biochar performance for contaminant at the field scale.	Yes
Brian Barry, PhD	Natural Resources Research Institute (NRRI)	Co-investigator: Dr. Barry is Chemistry and Materials Science Program Leader - Materials and Bioeconomy within NRRI; his research focuses on biochar production, characterization, agglomeration and inoculation for use as a soil amendment, as well as production of bio-based reductants from regionally relevant biomass resources	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 project will show the efficacy of using biochar derived from waste biomass sources such as dead and dying balsam fir in asphalt binders in both conventional asphalt mixes and mixes that contain a significant percentage of recycled materials such as RAP. Implementation could be aided by the installation of an industrial-scale microwave asphalt plant in NE Minnesota by (or during) 2024. If this development goes forward, access to such next-stage technology facility could allow the assembled research team's biochar findings to be tested and potentially implemented during the project. Success would leverage funding support from public and private entities.

Project Manager and Organization Qualifications

Project Manager Name: Lawrence Zanko

Job Title: Senior Research Program Manager/Researcher 7

Provide description of the project manager's qualifications to manage the proposed project.
Mr. Zanko is Senior Research Program Manager/Researcher 7 for Byproduct Reuse and Remediation within NRRI's Geology & Minerals Opportunity program. Since his start with NRRI in 1988, Mr. Zanko has led and managed or participated in a broad spectrum of research projects dealing with non-ferrous, ferrous, and industrial minerals. Research focus areas include mineral waste characterization, transportation infrastructure (construction aggregates and pavements), and 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 has been principle investigator and co-investigator on several past and current MnDOT-supported pavement-related projects, working with faculty of the University of Minnesota Duluth and Twin Cities; state, county, and local highway/public works engineers; state agencies; and the private sector, including taconite mines, aggregate producers, and a microwave technology provider.

Mr. Zanko received a Master of Geological Engineering, University of Minnesota, Twin Cities (UMTC); Bachelor of Geological Engineering (UMTC); and B.S. Microbiology (UMTC). He is a University of Minnesota Center for Transportation Studies Research Scholar, and a member and friend of the following committees of the Transportation Research Board of the National Academies: Resource Conservation & Recovery; Aggregates; and Pavement Maintenance.

Co-investigators include NRRI colleagues and biochar experts Bridget Ulrich, PhD, and Brian Barry, PhD; Professors Mihai Marasteanu and Jialiang Le, Department of Civil, Environmental, and Geo-Engineering, University of Minnesota Twin Cities; and Professor Manik Barman, Department of Civil Engineering, University of Minnesota Duluth. The latter specialize in formulating, collecting, and testing asphalt mixes, binders, additives; evaluating and testing pavements and pavement specimens; and data modeling.

Organization: U of MN - Duluth - NRRI

Organization Description:
The Natural Resources Research Institute (NRRI) is an applied research and economic development engine for the University of Minnesota research enterprise. NRRI employs over 130 scientists, engineers and technicians to deliver on its mission to deliver integrated research solutions that value our resources, environment and economy for a sustainable and resilient future. NRRI collaborates broadly across the University system, the state and the region to address the challenges of a natural resource based economy.

NRRI researchers have extensive experience in managing large, interdisciplinary projects. NRRI's role is as an impartial, science-based resource that develops and translates knowledge. Projects include characterizing and defining resource opportunities, minimizing waste and environmental impact, maximizing value from natural resources and maintaining/restoring ecosystem function.

The project will be led by NRRI's Geology & Mineral Opportunities Group, and will be comprised of a multidisciplinary team of researchers representing NRRI, UMD, and UMTC.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lawrence Zanko		Principal Investigator: Overall project management and coordination between University research teams (NRRI, UMD, and UMTC) and external collaborators from both the public and private sectors; project reporting			26.9%	0.3		$38,691
Mihai Marasteanu		Co-Investigator: formulating and testing asphalt mixes, binders, and additives; modeling of test/performance data; graduate student oversight and management of UMTC role			26.9%	0.15		$41,793
Manik Barman		Co-Investigator: formulating and testing asphalt mixes, binders, and additives; modeling of test/performance data; graduate and undergraduate student oversight and management of UMD role			26.9%	0.09		$13,556
Jialiang Le		Co-Investigator, Evaluation of binders and mix design, and modeling of the heat transfer process of microwave vs conventional asphalt heating			26.9%	0.06		$13,633
Mugurel Turos		Asphalt testing laboratory manager. Responsible for laboratory evaluation and testing of samples and specimens throughout the project			24.24%	0.39		$39,488
Sara Post		Field and laboratory involvement/coordination; data assembly; and report assembly/review			24.24%	0.3		$18,802
Brian Barry		Co-Investigator: Biochar material expertise			26.9%	0.09		$10,035
Bridget Ulrich		Co-Investigator: Biochar material expertise			26.9%	0.09		$10,300
Meijun Cai		Water chemistry related to pavement formulations and environmental considerations			26.9%	0.06		$7,141
Matthew Aro		LCA contributions			26.9%	0.12		$13,271
Zachary Wagner		Field and laboratory project assistance			24.24%	0.09		$4,658
Graduate Student, UMD		UMD graduate student will be involved in Years 2 and 3 of the project.			50.04%	0.25		$22,261
Graduate Student, UMTC		UMTC graduate student will be involved throughout the project			43.92%	0.5		$55,064
Undergraduate Student		General project assistance to UMD/NRRI, primarily during summer			0%	0.15		$4,914

Temp/Casual		General project assistance to NRRI			7.64%	0.09		$3,378
TBD Technician		General project assistance, with laboratory focus			24.24%	0.06		$4,758
George Hudak		Project review			26.9%	0.03		$6,201
Eric Singsaas		Project review			26.9%	0.03		$6,085
Matthew Young		Biochar production			24.24%	0.06		$6,326
Sam Firoozi		Biochar production			24.24%	0.06		$4,537
Oksana Kolomitsyna		Biochar characterization			26.9%	0.06		$5,025
Alex Kacharov		Biochar characterization			26.9%	0.06		$4,885
Stephen Monson Geerts		Microscopic and mineralogic characterization of materials			26.9%	0.06		$6,199
							Sub Total	**$341,001**
Contracts and Services								
To Be Determined	Professional or Technical Service Contract	External laboratory services for sample analysis: To cover costs of sample/specimen analysis/testing by external laboratories				0.03		$5,181
							Sub Total	**$5,181**
Equipment, Tools, and Supplies								
	Equipment	Laboratory microwave oven	One microwave oven will be purchased for use at UMTC partner laboratory.					$2,473
	Tools and Supplies	Lab supplies/consumables - UMD	Consumables and supplies needed to carry out various project tasks, including attachments/apparatus for collecting field specimens (cores) and for performing laboratory tests of samples and test specimens.					$2,613
	Tools and Supplies	Lab supplies/consumables - UMTC	Consumables and supplies needed to carry out various project tasks, including attachments/apparatus for performing laboratory tests of samples and test specimens					$3,090

	Tools and Supplies	Lab supplies/consumables - NRRI	Consumables for lab testing and analysis					$2,317
							Sub Total	**$10,493**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	The project location will likely be NE Minnesota, with meetings in Duluth or the Twin Cities campuses of the University of Minnesota, and with LCCMR as needed. Covers approximately 10,000 miles of vehicle travel at $0.31/mile, and 40 days of University vehicle usage at $35.83/day.	Vehicle mileage to cover field work, site visits, conference attendance, and meetings within Minnesota.					$4,636
	Conference Registration Miles/ Meals/ Lodging	Registration for project-related conferences (e.g., Minnesota Transportation Conference & Expo; UM Center for Transportation Studies Research Conference). 2 to 4 registrations per year per conference.	Attending and participating in professional conferences such as these will allow for the further dissemination of the project's findings to a broad audience of transportation officials, agencies, researchers, practitioners, and implementers					$3,090
	Miles/ Meals/ Lodging	To cover overnight lodging and per-diem field work, meetings, and conference attendance: Approx. $200/day; GSA rates for Duluth and Twin Cities. Estimated 5 to 7 nights per year (20 nights, total).	During the project, team members will periodically need to travel to the project location, attend project meetings, and attend conferences within Minnesota. These activities will require overnight lodging and meal expenditures.					$4,136
							Sub Total	**$11,862**
Travel Outside Minnesota								
							Sub Total	**-**

Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Sample Shipping Cost	To cover shipping of samples and materials					$463
							Sub Total	**$463**
							Grand Total	**$369,000**

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 55% 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	$188,993
In-Kind	Microwave Industry Consultants, LLC	Microwave Industry Consultants will contribute in-kind services for this project, totaling 80 hours at $250 per hour. The in-kind services contribution consists of technical consulting advice and consul	Secured	$20,000
			Non State Sub Total	**$208,993**
			Funds Total	**$208,993**

Attachments

Required Attachments

Visual Component

File: 8795d89c-e4b.pdf

Alternate Text for Visual Component

The visual depicts an asphalt highway converging on a sunrise (the future) and describes how the project team will apply its biochar and asphalt expertise to address national 2050 asphalt production objectives of net zero carbon emissions, net zero materials supply chain, and transition to electricity from renewable energy sources...

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
Microwave Industry Consultants In Kind Letter	50cf9838-3f3.pdf
UMD Sponsored Projects (SPA) Transmittal Letter	40050aed-918.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

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 design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

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?

No