Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-256

Proposal Title: Agrivoltaics to Combine Photovoltaics with Commodity Crop Farming

Project Manager Information

Name: Uwe Kortshagen

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Minnesota utilities need to transition to carbon-free energy by 2040. This project will determine the potential for agrivoltaic dual-use of land for commodity crop growth and photovoltaics in Minnesota.

Funds Requested: $425,000

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?

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.

Research has shown that dual-use of land for agrivoltaics, which combines crop production and photovoltaic (PV) electricity generation on the same land, leads to diversification and risk reduction for farmers, and to the creation of jobs in rural communities. However, to date, agrivoltaic implementations have mainly focused on the construction of solar farms with densely placed solar panels under which only shade tolerant crops or pollinator habitats can thrive. To fully realize the potential of agrivoltaics, it is imperative to explore strategies that are compatible with commodity crops such as corn, soybeans, and wheat, which are cultivated on more than 90% of harvested acres in Minnesota.

Although it is counter-intuitive to have shade-intolerant crops compete with photovoltaic arrays for light, there is significant research that indicates that mild shading of plants through sparsely placed solar panels does not significantly reduce crop yield, and leads to an overall gain if the price of the produced electricity is included. Moreover, partial shading may benefit some crops such as corn which does not grow when the temperature exceeds 90°F, and which require cooler nights late in the growing season (August) to reach desired yields. Partial shading from PV arrays may ameliorate these

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 establish the potential for agrivoltaic commodity crop farming in Minnesota. The focus will be on sparse solar arrays installed to be compatible with traditional corn-soybean farming practices. Based on our experience with modeling solar PV greenhouses and outdoor modules, we will develop a model that will describe solar electricity generation for agrivoltaic installations that provide small to moderate shading levels. PV array configurations will include strategies that are currently being evaluated around the globe, including PV arrays mounted on posts with one- or two-axis trackers and statically mounted bifacial panels. Crop yield will be estimated based on known photosynthetic response models. The model will use local historic weather data to predict PV electricity production. Factors that are specific to Minnesota, such as increased PV efficiency at low winter temperatures and high ground reflectivity due to snow cover will be included. The model will be validated with data from existing agrivoltaic systems provided by local utilities and agrivoltaic solar developers. After validation, the model will be used to map the overall agrivoltaic potential in Minnesota at the county level based on factors including local insolation and known agricultural crop yield.

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?

- House File 7 requires Minnesota utilities to transition to carbon-free energy by 2040. This project will explore the potential of photovolatic electricity generation on land co-used for corn, soybean, and wheat farming.
- The project will establish the potential for agrivoltaics at the county level.
- A model that will enable predicting PV and agricultural coproduction will be made available to the public through an interactive website.
- Outreach and educational efforts through the Great Plains Institute will communicate results of this project to stakeholders in the state.

Activities and Milestones

Activity 1: Build site-specific agrivolatics model

Activity Budget: $133,568

Activity Description:
This activity will build an agrivoltaics model that will be able to predict PV electricity generation and estimate crop yields based on insolation and shading averages over the growth season. We will consider different model agrivoltaic PV configurations: elevated panels with one- and two-axis tracking, and statically mounted bifacial panels. For each configuration, we will only study PV panel configurations that are compatible with current farming practices for corn, soybean, and wheat, providing enough room for farming equipment to operate between/under the panels. The insolation for any location in the state will be obtained from NASA's Surface meteorology and Solar Energy (SSE) data archive. Plant shading values throughout the growth season will be derived from geometric considerations. Using published photosynthetic efficiency data, we will estimate the potential crop yields and potential reductions through shading. PV electricity generation will be modeled for the entire year, including temperature-dependent changes of PV efficiencies and enhanced PV generation through large reflectivity due to snow cover. The model will be validated based on data from research projects at Purdue University, the West Central Research and Outreach Center in Morris, MN, and partners identified by the Great Plains Institute.

Activity Milestones:

Description	Approximate Completion Date
Determine shading levels for model agrivolatic configurations during growth season	December 31, 2024
Model year-round PV generation including temperature-dependent efficiency and seasonal ground reflectivity	June 30, 2025
Model validation based on available experimental data	December 31, 2025

Activity 2: Mapping agrivoltaic potential in Minnesota

Activity Budget: $142,230

Activity Description:
The model developed and validated under activity 1 will be used to determine the overall agrivoltaic potential in Minnesota. For each Minnesota county, we will use data for harvested acres published by the USDA. Based on a county's insolation throughout the year and over the growth season, we will explore the optimal agrivoltaic configuration that optimizes PV generation and crop yield. The data will be made available to the public through a dedicated project website. We will also develop an interactive version of our model that will be hosted on the website. Interested stakeholders will be able to explore conditions for PV generation and crop yield based on custom configuration choices for any location in Minnesota.

Activity Milestones:

Description	Approximate Completion Date
Determine optimal agrivoltaic configuration and overall agrivoltaic potential for every Minnesota county	December 31, 2026
Publication of data and interactive agrivoltaic model through a dedicated project website	June 30, 2027

Activity 3: Community outreach and engagement

Activity Budget: $149,202

Activity Description:

Minnesota is the third largest corn producer in the US, and agriculture is a primary export component of Minnesota's economy, and the local economy of many host communities. Moving to agrivoltaics as a model for solar development creates local co-benefits and keeps prime farmland in production while also producing clean energy. Great Plains Institute (GPI) actively participates in developing new solar use cases that provide benefits to local communities and integrate agrivoltaic benefits into farmland protection goals and land use standards that affect the viability of and market for agrivoltaics. GPI will collect data to enable model validation and agrivoltaic mapping by working with solar developers, owners of existing solar projects, off-takers such as utilities, host communities, agricultural interests, and transmission owners and planners. Data includes production profiles from solar farms, consistency of agrivoltaics with state and local land use goals and regulations, wholesale and retail market opportunities for off-takers, utility contracts and rate structures, planned transmission investments and capacity, and other data that affect the viability of agrivoltaics. In the latter half of the project, GPI will work with its community partners communicate the results of this project and the potential benefits of agrivoltaics to stakeholders in the state.

Activity Milestones:

Description	Approximate Completion Date
Gather data from community partners for model validation and agrivoltaic mapping	December 31, 2025
Communicate results and educate stakeholders about benefits of agrivoltaics	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Vivian E. Ferry	University of Minnesota - Twin Cities	Vivian Ferry is an Associate Professor in the Department of Chemical Engineering and Materials Science at the University of Minnesota. She is an expert in innovative photonic concepts. She has experience in modeling outdoor installations of photovoltaic modules.	Yes
Brian Ross	Great Plains Institute	Brian Ross, AICP, LEED GA, is a Vice President at the Great Plains Institute, leading GPI's renewable energy market transformation efforts. He managed stakeholder engagement and technical committee facilitation for the MN Solar Pathways project and will play a similar role for this project.	Yes
Monika Vadali	Great Plains Institute	Monika Vandal is a senior project manager for renewable energy. Her work currently involves developing state, local, and national collaborations for renewable energy grant projects with equitable partnerships and solutions as a focus.	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 proposed research will help establish the full potential of photovoltaic and commodity crop farming co-use of land. Once this is achieved, we expect that there will be significant interest both by federal funding agencies, utilities, and agricultural producers. The team will pursue research funding from the Advanced Research Projects Agency-Energy (ARPA-E), the Department of Energy, and the National Science Foundation.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Develop Solar Window Concentrators for Electricity	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 07a	$350,000

Project Manager and Organization Qualifications

Project Manager Name: Uwe Kortshagen

Job Title: Professor

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

Professor Kortshagen will manage the overall effort. He has considerable leadership experience with multi-investigator teams, having led three interdisciplinary research groups of the National Science Foundation-funded UMN Materials Research Science and Engineering Center from 2007-2021. He also directs an Army Research Office funded Multidisciplinary University Research Initiative project, involving partners at Caltech, the University of Michigan, University of Iowa, and Washington University at St. Louis. He also gained significant management experience by serving for 10 years as Head of the Department of Mechanical Engineering at the University of Minnesota, which comprises more than 40 faculty, 40 staff members, and ~280 graduate students with an annual combined operations, maintenance, and research budget of ~$26M, while still managing his research group of about 15 graduate students.

Kortshagen has significant experience in basic and translation research. He and his research group have worked on photovoltaic devices for the past 15 years and his group now works on photovoltaics for greenhouses and farming. His work has been published in more than 230 scientific articles in peer-reviewed journals. His invention of silicon nano-particle inks produced by plasmas has been patented by the University of Minnesota and licensed to a total of four

industrial partners. He was issued 4 patents that generated royalty income exceeding $1M and led to 2 start-up companies.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota offers world-class infrastructure for this project. The team has access to a large number of computational facilities at the University of Minnesota Supercomputing Institute. While we do not anticipate needing massive computational resources for this project, the team will have access to a HP Linux cluster with 1091 HP ProLiant BL280c G6 blade servers, each with two quad-core 2.8 GHz Intel Xeon X5560 "Nehalem EP" processors sharing 24 GB of system memory, with a 40-gigabit QDR InfiniBand (IB) interconnect; a constellation of SGI systems, including foremost an Altix UV 1000 node with 1,140 compute cores (190 6-core Intel Xeon X7542 "Westmere" processors at 2.66 GHz) and 2.96 TiB of globally-addressable shared memory; and an SGI Altix XE 1300 cluster with 180 compute nodes, each with 16 GB of memory.

The project partner Great Plains Institute is an organization of leaders and experts dedicated to engaging and collaborating with people, organizations, and communities to craft nonpartisan, pragmatic energy solutions that benefit the economy and environment.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Uwe Kortshagen		Principal Investigator / Project Manager (UMN-TC)			27%	0.15		$55,268
Vivian Ferry		co-Principal Investigator: agrivoltaic modeling, UMN-TC			27%	0.15		$26,677
Graduate Student Researcher		1 graduate student researchers in Chem. Eng. Mat. Sci, UMN-TC			42%	1.5		$190,560
Brian Ross, VP, GPI		Research, stakeholder recruitment and engagement, oversight and quality control			24%	0.15		$36,321
Monika Vadalia, Senior Manager, GPI		Research, stakeholder engagement, modeling			24%	0.45		$73,070
Program Assoc., GPI		Research, stakeholder engagement, project support			24%	0.48		$39,813
							Sub Total	**$421,709**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
							Sub Total	-
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-

Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel of project participants between UMN-Twin Cities and stakeholder in MN	Travel to discuss project progress, visit partner sites, participate in off-campus research					$3,291
							Sub Total	**$3,291**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$425,000**

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	Unrecovered F&A	Support of Mechanical Engineering facilities where research will be conducted.	Secured	$136,678
			Non State Sub Total	**$136,678**
			Funds Total	**$136,678**

Attachments

Required Attachments

Visual Component

File: a08867ae-d99.pdf

Alternate Text for Visual Component

The image demonstrates the modeling approach of studying different agrivoltaic configurations to determine optimal photovoltaic electricity production and crop yield. The model will be used to study agrivoltaic potential in the state at the county level....

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
Support Letter from Sponsored Projects Administration.	b697cb31-67c.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?

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?

Yes, Sponsored Projects Administration

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