Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-410

Proposal Title: Future Availability of Solar Energy in Minnesota

Project Manager Information

Name: Ardeshir Ebtehaj

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: Current solar energy potential estimates in Minnesota rely on historical data, overlooking climate change impacts on cloud cover. We aim to project future solar energy availability under various climate scenarios.

ENRTF Funds Requested: $339,000

Proposed Project Completion: July 31, 2029

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?

In the Future

Narrative

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

Minnesota's solar industry is rapidly growing, supported by community solar programs, utility investments, and strong legislative policies. A report by the Minnesota Department of Commerce projects that solar and wind could supply 70% of the state's electricity by 2050. However, these projections rely on historical data and do not account for the potential impacts of climate change on solar energy availability, raising concerns about their accuracy.

The efficiency of solar panels depends on the amount of sunlight reaching the Earth's surface, typically measured by daily sun hours. Future changes in cloud cover driven by global warming could significantly alter Minnesota's solar energy potential. Will the state become cloudier or sunnier in a warming climate? Will these changes vary regionally? Answering these questions is critical for making realistic renewable energy projections.

According to the Minnesota Department of Natural Resources (DNR), Minnesota has warmed by about 3°F and received 3.4 inches more annual precipitation since 1895. Increased evaporation from lakes and forests may enhance low-level cloud formation, potentially reducing solar radiation. Yet, no study has explored how climate change may impact future solar energy potential in Minnesota — a critical knowledge gap for sustainable energy planning.

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 proposal aims to quantify how global warming will impact solar energy availability across Minnesota over the next century and assess its implications for future solar energy harvesting.

To achieve this, we will analyze projections of solar radiation and cloud cover from the Coupled Model Intercomparison Project Phase 6 (CMIP6). CMIP6 includes over 33 state-of-the-art global climate models (GCMs) that simulate past (1850-present) and future (up to 2100) climate changes under various greenhouse gas emission scenarios, known as Shared Socioeconomic Pathways (SSPs). These scenarios capture a wide range of potential future socio-economic and environmental conditions, from low to high global economic activities.

However, GCMs differ significantly in their underlying mathematical and physical assumptions, resulting in varying predictions with inherent uncertainties. A key challenge is determining which models most accurately represent past climate conditions over Minnesota to improve future projections. This proposal will evaluate the historical performance of all 33 models and identify the most reliable ones for predicting future solar energy potential. The findings will provide critical insights for policymakers, utilities, and investors to optimize solar energy development across Minnesota in a changing climate.

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?

This project will provide predictive assessments, maps, and an online platform to evaluate how climate change may impact long-term solar energy availability in Minnesota, supporting sustainable energy planning. By analyzing climate projections, we will identify trends in solar irradiance and cloud cover under different SSP scenarios, along with their uncertainties. The resulting maps will highlight solar energy potential for electricity production across the state. These insights will help policymakers optimize solar investments, promoting energy resilience. Ultimately, this research will advance clean energy adoption, minimize environmental degradation, and support climate adaptation strategies, contributing to a more sustainable energy portfolio for Minnesota.

Activities and Milestones

Activity 1: Process and rank the quality of CMIP6 climate projections of solar radiation over Minnesota

Activity Budget: $106,680

Activity Description:
Our research will focus on analyzing all historical simulations from climate models in the CMIP6 project. We will compare these simulations with available NASA satellite observations from recent decades to assess the accuracy of each model in simulating solar radiation and cloud cover over Minnesota. This comparison will allow us to rank the models based on their performance and reliability in representing local climate dynamics. By identifying the best-performing models, we will provide more accurate projections of future solar energy potential, helping guide effective energy planning and decision-making in the face of climate change.

Activity Milestones:

Description	Approximate Completion Date
Download and pre-processing of CMIP6 data from past (1950-present)	December 31, 2026
Compare the historical CMIPS simulations with satellite and in situ observations	February 28, 2027
Statistical ranking of CMIP6 models over Minnesota using statistical techniques	May 31, 2027
Disseminate the results through peer-reviewed publications	August 31, 2027

Activity 2: Mapping the availability of solar energy in the next century under different climate change scenarios

Activity Budget: $114,790

Activity Description:
We will select the top 10 climate models from the CMIP6 project (Activity 1) and analyze their future predictions of solar irradiance and cloud cover. Using advanced statistical techniques, we will identify trends in solar energy production, particularly focusing on changes in daily sun hours. This analysis will allow us to assess whether solar energy potential is expected to increase or decrease due to global warming. We will generate maps that highlight regions in Minnesota where solar electricity generation potential may grow or shrink, providing valuable insights for households and stakeholders in different parts of the state. These maps will inform local energy strategies and help optimize solar investments across the state in the face of climate change.

Activity Milestones:

Description	Approximate Completion Date
Statistically analyze the prediction of solar radiation by the top 10 CMIP models	November 30, 2027
Identify the difference and quantify uncertainties of climate projections of solar energy potentials	February 28, 2028
Produce maps delineating the impacts of climate change on regional solar energy production	August 31, 2028
Disseminate the results through peer-reviewed publications and reports	January 31, 2029

Activity 3: Develop an online web tool to make the findings available to stakeholders

Activity Budget: $117,530

Activity Description:
We will create publicly accessible predictive maps of solar energy potential, illustrating future electricity generation possibilities under different climate change scenarios across Minnesota. These maps will provide both households and

state agencies with insights into the minimum and maximum potential electricity generation for each month of the year. To enable user interaction, we will develop a GIS-based web platform powered by Google Colab (https://colab.research.google.com/), allowing users to explore and visualize the data. For example, users can input the latitude and longitude of their location, along with solar panel efficiency and surface area, to estimate potential electricity generation over the next 75 years, with insights into how it may evolve over time. This interactive tool will empower households, businesses, and policymakers to make informed decisions on renewable energy investments, supporting sustainable energy development in Minnesota.

Activity Milestones:

Description	Approximate Completion Date
Development of inline GIS maps of future solar energy production for different SSPs	March 31, 2029
Integration with Google Platform and online GIS and public dissemination	July 31, 2029

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?

We will develop a web-based Geographic Information System (GIS) to provide accessible solar energy data for Minnesotans, policymakers, and agencies, including the Department of Natural Resources and Commerce. To ensure long-term sustainability, the platform will be designed to incorporate future updates from CMIP6 and beyond. Continued implementation will be pursued through state and federal grants, partnerships with academic institutions, renewable energy organizations, and integration with existing state initiatives. This platform will support informed decision-making, helping optimize solar energy investments and advance Minnesota's clean energy transition in a changing climate.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Remote Sensing And Super-Resolution Imaging Of Microplastics	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08j	$309,000
Fate of Minnesota's Lakes in the Next Century	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 03d	$453,000
Hyperspectral Characterization of Toxic Harmful Algal Blooms	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 04a	$399,000

Project Manager and Organization Qualifications

Project Manager Name: Ardeshir Ebtehaj

Job Title: Associate Professor

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

Ardeshir Ebtehaj will be responsible for overall project coordination and supervision of the study, including analysis of climate models using statistical tools and web-based tools to make the project results available to the stakeholders. He has studied remote sensing and climate change impacts on rain, snow, and clouds for more than 17 years. He has conducted peer-reviewed research in satellite remote sensing and climate change impacts on precipitation, clouds, soil moisture, lakes, vegetation, snow, and plastic pollution in freshwater ecosystems. He has been the PI for numerous NASA projects and three LCCMR projects. He has published over 55 peer-reviewed papers and co-authored a book chapter on remote sensing of the environment in the Handbook of Environmental Engineering in 2019. Dr. Ebtehaj is an editor of the Journal of Hydrometeorology, an affiliate member of the University of Minnesota Institute on the Environment, and a member representative of the University of Minnesota in the University Centers for Atmospheric Research (UCAR). He received an editor award from the American Meteorological Society, NASA's Earth and Space Science Fellowship in 2014, and NASA's New Investigator (Early Career) award in 2018 for his contribution to Earth's remote sensing sciences.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:

The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://twin-cities.umn.edu/about-us). The laboratories and offices of the PI contain the necessary fixed and moveable equipment and facilities for the proposed studies. The PI will conduct the research in the Saint Anthony Falls Laboratory. The St. Anthony Falls Laboratory (SAFL) is an interdisciplinary hydraulic research lab and educational facility under the College of Science and Engineering at the University of Minnesota. Located on Hennepin Island in the

Mississippi River in the heart of Minneapolis, SAFL serves as a resource for departments across the Twin Cities campus, the statewide University system, and the broader research community. We partner with local, state, and federal agencies, private consulting firms, businesses of many kinds, technical associations, and other educational institutions to expand knowledge and solve problems. The PI will use the Minnesota Supercomputing Institute faculty to analyze promises computation. MSI offers more than 125 million hours of free computing annually to University of Minnesota faculty and collaborators. Access is determined by the "fair share" algorithm in the SLURM system.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Associate Professor		Project management of the first year of the project			36.6%	0.13		$24,566
Postdoctoral scholar		Data analysis and execution of the first year of the project			25.9%	1		$79,113
Associate Professor		Project management of the second year of the project			36.6%	0.13		$25,304
Postdoctoral Scholar		Climate data analysis and mapping for the activities of the second year of the project			25.9%	1		$81,486
Associate Professor		Project management of third year of the project			36.6%	0.13		$26,062
Postdoctoral scholar		GIS and web-based platform developments.			25.9%	1		$83,931
web designer		Professional service for computational and web design services -- 2nd year of the project			36.6%	0.05		$5,000
Web-designer		Professional service for computational and web design services -- 3rd year of the project			36.6%	0.05		$5,000
							Sub Total	**$330,462**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
							Sub Total	**-**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	3 open access publications	dissemination of the finding to the public					$8,538
							Sub Total	**$8,538**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$339,000**

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: $339,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 16d7290d-ee1.pdf

Alternate Text for Visual Component

The flow of the proposal activities....

Supplemental Attachments

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

Title	File
Endorsement Letter by SPA	4b374ab0-ecc.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?

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?

Yes, Sponsored Projects Administration

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:

Victoria Troxler

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