



Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-256

Proposal Title: Cultivating Sustainable Food Systems with Deep Winter Greenhouses

Project Manager Information

Name: Natasha Wright

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We will improve the efficiency and profitability of deep winter greenhouses, bridging growing seasons and creating resilient food systems via passive solar growing in winters and solar drying in summers.

ENRTF Funds Requested: \$306,000

Proposed Project Completion: June 30, 2028

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.

Deep Winter Greenhouses (DWGs) have emerged as a Controlled Environment Agriculture (CEA) technology, i.e. one that can control growing conditions within desired parameters. DWGs are designed to allow operators to grow crops regardless of their bioregion, thereby enabling resilient food systems amidst a changing climate. Unlike conventional greenhouses, which are energy intensive in cold climates such as Minnesota, DWGs are designed to source the majority or entirety of their required wintertime heating energy passively from the sun. This enables DWGs to have 2-3 times lower global warming potential than conventionally heated greenhouses (Clune, 2017). DWGs also enable alternate uses during summer months, such as passive solar drying of produce. Their simple design increases access to CEA by small family farms, which comprise over 80% of Minnesota farms (USDA, 2017).

DWG designs can achieve minimal supplemental heating by admitting solar heat through transparent glazing and storing that heat in an underground thermal mass of soil or crushed rock during the day. Overnight, the stored heat is released to condition a heavily insulated growing space to stabilize temperatures and maintain an environment suitable for growing crops. An opportunity exists to expand upon the current research and reach of DWGs in MN.

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.

UMN researchers seek funds to model and optimize DWG rock-bed thermal storage, explore alternative heat storage methods, and expand reach throughout the state. An environmental and economic sustainability analysis and collaboration with Minnesota farms will provide further insight into how DWGs can be leveraged to reduce the environmental impact of agricultural practices and enable resilient food systems.

While past emphasis of DWGs has been on use during extreme winter conditions, they also have the potential for unique applications during summer months when DWGs can be used as controlled-environment passive solar dryers for food preservation, creating circular food systems through value-added products that divert food loss as well as prevent the loss of the accompanying embedded energy and resources.

Our team will leverage previous research on and field installations of DWGs by the UMN Center for Sustainable Building Research and UMN Extension Regional Sustainable Development Partnerships, including the five (already funded) farm-scale DWGs that will be constructed throughout the state in 2024 and 2025. These greenhouses will serve as the baseline for the proposed study, as we aim to minimize or eliminate auxiliary heating, optimize for affordable construction with a low carbon footprint, and maximize reach and profitability.

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?

We aim to advance the efficiency of and increase access to DWGs, positioning Minnesota farmers to profitably adapt to changing climate conditions. Efficiently growing crops cultivates more resilient food systems and reduces threats of local and worldwide production that may become limited due to hotter and drier conditions under current production schemes. In addition to climate change adaptation, DWGs offer the opportunity to mitigate environmental impacts of agriculture by leveraging natural solar resources and innovative designs to reduce greenhouse gas emissions and maximize immediate and future benefits for communities and ecosystems across the state.

Activities and Milestones

Activity 1: Develop and validate an integrated model that couples the behavior of the greenhouse with the thermal rock bed storage.

Activity Budget: \$149,071

Activity Description:

While available software can be used to model the performance of standard greenhouses, neither this software nor the academic literature contain models to describe the coupled behavior of greenhouses with thermal storage (i.e., as is required in a DWG) in a way that allows for translation to new design concepts, iteration, and optimization. We will develop the required model in Python, making it free to use and distribute to future DWG engineers.

We will validate this new model. As part of a separate project, UMN Regional Sustainable Development Partnerships will be installing five farm-scale DWGs with community partners in 2024-2025. As part of that project, a temperature sensor array and data acquisition unit will be installed in one of the DWGs. In order to fully validate the DWG model developed for Milestone 1 and understand key energy drivers, however, we will upgrade that sensor system to capture human events (e.g. opening of windows and doors) and ambient weather conditions. One month of summer and one month of winter data from the full sensor array will be used to improve model fidelity for both winter growing and summer drying.

Activity Milestones:

Description	Approximate Completion Date
Initial model integration; prediction of annual auxiliary heating needed and temperature profile within the greenhouse.	December 31, 2025
Installation of additional sensors; at least 2 months of data from installed DWG processed.	June 30, 2026
Data from Milestone (2) used to improve model fidelity.	December 31, 2026

Activity 2: Update the system model to enable assessment of alternative architectures, energy storage, and energy delivery options.

Activity Budget: \$79,280

Activity Description:

Once we understand the performance of the current DWG design, both analytically and via data collection from field installations (from Activity 1), we will update the model to consider alternative designs. This will include (i) alternative greenhouse geometries (e.g. relative size of the south facing “window” wall to the overall greenhouse volume), (ii) alternative options for thermal storage (e.g. concrete-and-tube or earth-and-tube), (iii) alternative options for auxiliary heat equipment (e.g. solar heat pump). To select the scenarios for analysis, we will conduct a parametric analysis of the model developed in Activity 1 and work closely with partners at Extension Regional Sustainable Development Partnerships and the Center for Sustainable Building Research to understand previous DWG iterations and options considered, including the real-world context and potential limitations of those options they have already uncovered.

Activity Milestones:

Description	Approximate Completion Date
Conduct parametric analysis to uncover components of the design with greatest impact on performance.	March 31, 2027
Determine alternative design scenarios worthy of model extension.	June 30, 2027
Update model to incorporate alternative design scenarios.	September 30, 2027

Activity 3: Conduct techno-economic and environmental impact assessment with feedback from public demonstration of farm scale winter greenhouse technology.

Activity Budget: \$77,649

Activity Description:

In this activity, we will work to understand the ‘tradespace’ between DWG environmental, economic, and educational goals. We will conduct an environmental impact assessment for an installed farm-scale DWG. We will then assess the impact of the newly proposed designs (identified in Activity 2, Milestone 3), comparing the greenhouse gas emissions of the current DWG design to those alternatives, and to conventional greenhouses.

For the economic assessment, the team will leverage and extend previous work by the UMN Agricultural Business Management Office to analyze return on investment. Additionally, UMN Extension RSDP will host public open houses of three DWGs in Minnesota. These events will invite the public to learn about the benefits of passive solar winter food production infrastructure, the current DWG functionality, and winter food production techniques. It will also be an opportunity for our team to survey farmers about both the value in and concerns regarding integrating such a system into their farms. We will summarize the relative economic and environmental impacts. These analyses are sensitive to the location of installation, and therefore one key objective will be to uncover the potential benefits and drawbacks of installation in different regions of the state.

Activity Milestones:

Description	Approximate Completion Date
Conduct first two public demonstration and feedback events.	June 30, 2027
Develop environmental impact assessment for baseline farm-scale DWG.	June 30, 2027
Develop environmental impact assessment for newly proposed DWG designs with comparison to baseline.	December 31, 2027
Conduct a third public demonstration and feedback event.	March 31, 2028
Summarize environmental and economic tradespace in a final report.	June 30, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Greg Schweser	Sustainable Agriculture and Food Systems, UMN Regional Sustainable Development Partnerships	Coordinate Farm Scale Deep Winter Greenhouse outreach events. Meet monthly with research team to provide insight on farmer contextual factors relevant to design direction.	Yes
Carol Ford	UMN Extension Regional Sustainable Development Partnerships	Carol Ford is the program coordination for UMN Extension. She will conduct the public education and demonstration on winter crop production at the three community events.	Yes
Dan Handeen	UMN Center for Sustainable Building Research	Conduct public education and demonstration of the farm-scale DWG technology at the three community events. Meet monthly with the PI and lead research student to discuss model development and progress.	Yes
Ryan Pesch	UMN Agricultural Business Management Regional Office Moorhead	Conduct economic surveys with private farmers regarding farm-scale DWG as part of Activity 3 economic analysis.	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?

We will pursue National-scale funding for this project through the Department of Energy. This agency has previously supported our research and field testing on other projects related to decentralized energy systems. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Managing Highly Saline Waste From Municipal Water Treatment	M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04a	\$250,000

Project Manager and Organization Qualifications

Project Manager Name: Natasha Wright

Job Title: Assistant Professor of Mechanical Engineering

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

B.S., Mechanical Engineering, University of St. Thomas, St. Paul, MN

M.S., Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA.

Ph.D., Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA. Post-Doctoral Associate, Environmental Engineering, 2019, University of Minnesota

Natasha Wright (Assistant Professor, Mechanical Engineering) will be responsible for the overall project coordination. Her research group at the UMN focuses on the design and system optimization of decentralized energy and water systems. She will complete an LCCMR-funded project on the design and real-time optimization of convection enhanced evaporation processes in June 2024. That project has led to one granted patent and four journal publications. Over the last 10 years, she has piloted energy-water systems in the United States, India, and Gaza.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (<https://twin-cities.umn.edu/about-us>). The laboratories and offices of the PI and co-PIs contain all of the necessary fixed and moveable equipment and facilities needed for the proposed studies.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Principal Investigator (Natasha Wright)		Overall program management and oversight; director mentorship of graduate student researcher. 1 month/year, 3 years, including UMN rate of 37.1% benefits.			27.1%	0.24		\$51,705
Graduate Researcher		Analytical model extension, conduct data collection and experimental validation. Includes UMN rate of 25.1% benefits plus tuition.			43.6%	1.5		\$183,155
Undergraduate Researcher		Assist graduate student researcher with field data collection and processing. 1 students for 5 hours/wk at \$16/hr.			0%	0.24		\$8,320
Field Coordinator (Greg Schweser)		Coordinate Farm Scale Deep Winter Greenhouse outreach events. Meet monthly with research team to provide insight on farmer contextual factors relevant to design direction. 1 week/year, 3 years, including UMN rate of 37.1% benefits.			27.1%	0.06		\$6,603
Field Coordinator (Carol Ford)		Conduct public education and demonstration on winter crop production at three DWG outreach events. 1 week/year, 3 years, including UMN fringe rate of 7.7% for hourly employees..			7.2%	0.06		\$3,212
Agricultural Business Specialist (Ryan Pesch)		Conduct economic surveys with private farmers regarding farm-scale DWG design. 2 weeks in Year 2. Including UMN rate of 37.1% benefits.			27.1%	0.04		\$4,799
Field technology specialist (Dan Handeen)		Conduct public education and demonstration of farm-scale DWG technology. Meets regularly with PI and graduate student researcher to review design directions. 2 weeks/year, 3 years, including UMN rate of 37.1% benefits.			27.1%	0.12		\$13,953
							Sub Total	\$271,747
Contracts and Services								
							Sub Total	-

Equipment, Tools, and Supplies								
	Tools and Supplies	Life-cycle inventory database procurement.	Necessary to conduct environmental assessment described in Activity 3.					\$4,150
	Tools and Supplies	Weather station, temperature/humidity/airflow/state sensors, and data acquisition equipment	Needed to fully outfit one field installed DWG for model validation.					\$17,603
							Sub Total	\$21,753
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	Miles: 4 trips to MN-based DWG annual for PI and graduate researcher, extension staff (2 vehicles / trip)	Sensor installation, DWG performance monitoring, annual community engagement event					\$3,200
							Sub Total	\$3,200
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	2 people (PI and graduate researcher); flight, 3 nights hotel, food, conference registration	Attendance at 1 US-based professional conference to present the findings of this research	X				\$2,800
							Sub Total	\$2,800
Printing and Publication								
	Publication	Journal publication fees (x2)	To make published journal articles immediately available via open access to maximize data availability and dissemination					\$5,000
							Sub Total	\$5,000

Other Expenses								
		Farmer Stipends	\$500 provided to each of 3 farmers who support the project by allowing their DWG to be the base for the community outreach events.					\$1,500
							Sub Total	\$1,500
							Grand Total	\$306,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	2 people (PI and graduate researcher); flight, 3 nights hotel, food, conference registration	Formal presentation of project findings

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
In-Kind	University of Minnesota	Because the project is overhead free, laboratory space, electricity, and other facilities/administrative costs (55% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	Secured	\$138,584
			Non State Sub Total	\$138,584
			Funds Total	\$138,584

Total Project Cost: \$444,584

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: [50765e35-781.pdf](#)

Alternate Text for Visual Component

The basic principle of deep winter greenhouses is shown, where solar energy is absorbed during the day and released at night. The benefits of deep winter greenhouses are compared to conventional greenhouses and hoop houses, noting the potential for reduced energy and economic burden....

Supplemental Attachments

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

Title	File
UMN Letter of Support from Sponsored Projects Administration	73fa100d-2cc.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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:

N/A