Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 178-E**

Deep Winter Greenhouses: Passive Solar Winter Food Production

Category: E. Air Quality, Climate Change, and Renewable Energy

Sub-Category:

Total Project Budget: $ 1,559,706

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

The University of Minnesota will improve and advance a highly energy and water efficient passive solar Deep Winter Greenhouse (DWG) to reduce the carbon footprint of winter food production.

Name: Greg Schweser

Sponsoring Organization: U of MN

Job Title:

Department: Extension, Regional Sustainable Development Partnerships

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Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Examples of Deep Winter Greenhouses; Visual diagram of how DWG system operates; and a map of known DWGs in Minnesota

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Deep Winter Greenhouses: Passive Solar Winter Food Production

I. PROJECT STATEMENT

Goal: This project will improve and advance a passive solar Deep Winter Greenhouse (DWG) to reduce the carbon footprint of winter food production. Developed by the University of Minnesota, DWGs capture solar heat during cold winter days and store it underground in an insulated thermal mass of crushed rock where it is available for use at night to keep the indoor growing space warm. A few dozen DWGs utilized by early adopters are highly experimental but have demonstrated dramatic reductions of fossil fuel usage compared to conventional greenhouses. However, the precise interplay between underground heated air flow and building performance is not yet known. With this information, architects will design DWGs at various scales that, combined with economic and supply chain research, will remove barriers to adoption and prepare the system for deployment across Minnesota.

How project achieves goal: UMN researchers and building designers, partnering with existing DWG farmers will conduct thorough analyses of insulated rock beds, internal and subterranean air flow, perform lifecycle analysis of building materials, and improve DWG design for onsite water capture, reuse, and runoff reduction. In addition, researchers will conduct plant trials to maximum production and conduct economic analyses of supply chain and market demand to determine appropriate market scales and price points for market deployment. Extension will incorporate results into workshop curriculum and online resources available to the public.

Why project needs to be done: DWG technology reduces greenhouse gas emissions by minimizing fuel, energy, and water inputs. Sophisticated research is needed to improve the design and building performance to advance DWG technology from an experimental stage to a fully deployable DWG building design and a winter food production model. Once this project is complete, widespread adoption of DWG systems will occur and provide an economic opportunity for urban and rural Minnesotans and strengthen the sustainability of the US food system.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Research to develop DWG building design and improve efficiency and lifecycle performance

Description: Conduct research that includes analysis of thermal rock bed airflow, life cycle analysis, climate analysis, water use analysis and design modification. **ENRTF BUDGET:** $654,547

Outcome	Completion Date
1. Thermal rock bed airflow analysis: Study DWG rock beds to research heat transfer, fluid flow, and control to develop a computational model of efficient rock bed parameters.	*6/2022*
2. Life Cycle Analysis: Identify environmental impacts of DWG structural components, mechanical operations, and production methods to compare with conventional vegetable production and transportation systems.	*1/2023*
3. Climate Analysis: Analyze historic and projected trends in climate to estimate impacts of rainfall frequency and volume, cloud cover, solar access, drought, temperature and humidity to determine relationships to DWG and associated water storage design characteristics.	*4/2023*
4. Water use analysis: Determine water use impacts of a Minnesota food system integrated with DWG production systems and identify design characteristics that incorporate on-site water storage and use.	*7/2022*
5. Design: Integrate research findings to improve and prepare DWG design to establish a new industry for Minnesota farmers and promote large-scale adoption that results in energy efficient winter vegetable production, reduction in ghg emissions and carbon foot-print, and efficient water in the vegetable production system.	*6/2023*

Activity 2 Title: Horticultural production and supply chain research
Description: Horticultural production research and supply chain research to identify the profit points and scale necessary to establish a DWG food production industry in Minnesota. **ENRTF BUDGET:** $366,693

Outcome	***Completion Date***
1. Horticulture: Investigate impacts of new hyper-energy efficient LED lighting technologies, identify optimal vapor pressure deficits, and maximize post-harvest performance of 50-100 select optimal varieties for scalability and production in a DWG system.	*4/2023*
2. Supply Chain and Market Analysis: Analyze supply chains at multiple production scales and conduct annual market analysis for DWG crops. Identify target production efficiencies and optimal production scales for adoption of DWG technology.	*6/2023*

Activity 3 Title: UMN Extension Education and Outreach
Description: Disseminate project results and host DWG workshops to existing and new DWG producers, energy efficiency building professionals, and University of Minnesota students **ENRTF BUDGET:** $538,466

Outcome	**Completion Date**
1. Operation and Production Assistance: Extension experts will provide production and building operation assistance to existing and new DWG operators.	*6/2023*
2. Outreach activities: Host first Global Energy Efficiency Deep Winter Food Production conference to bring together 250-300 experts, farmers, and passive solar greenhouse pioneers to present work; Conduct 3-5 annual field days in DWGs; host annual DWG webinars to a total audience of 1500-2000.	*1/2023*
3. Education: Incorporate DWG project findings into 3 formal University of Minnesota mechanical engineering, design, and horticulture courses.	*4/2023*

Total Budget: $1,559,706

III. PROJECT PARTNERS AND COLLABORATORS:

Project Partners and Collaborators Receiving Funding: University of Minnesota collaborating departments: University of MN Extension RSDP; Department of Mechanical Engineering Solar Energy Lab; College of Design Center for Sustainable Building Research, CFANS West Central Research and Outreach Center; CFANS Department of Horticulture; CFANS Department of Climatology; Institute on the Environment Global Water Initiative; Carlson School of Management; Participating DWG farm operators: Shayne and Louise Johnson (Grampa Gs Farm); Jack Judkins (Bemidji Community Food Shelf Farm); Sara and Paul Freid (Lake City Catholic Worker Farm).

Project Supporters: Round River Farm, David Abazs, Finland, MN; **Organic Consumers Association**, Finland, MN, Stefan Meyer**; Conservatory Craftsmen**, Dick Hewitt -- Greenhouse Manufacturer; **Compeer Financial**, Sai Thao -- Lending officer; **MN Farmers Market Association**, Kathy Zeman -- Executive Director; **Sustainable Farming Association of MN**, Theresa Keaveny, Executive Director

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

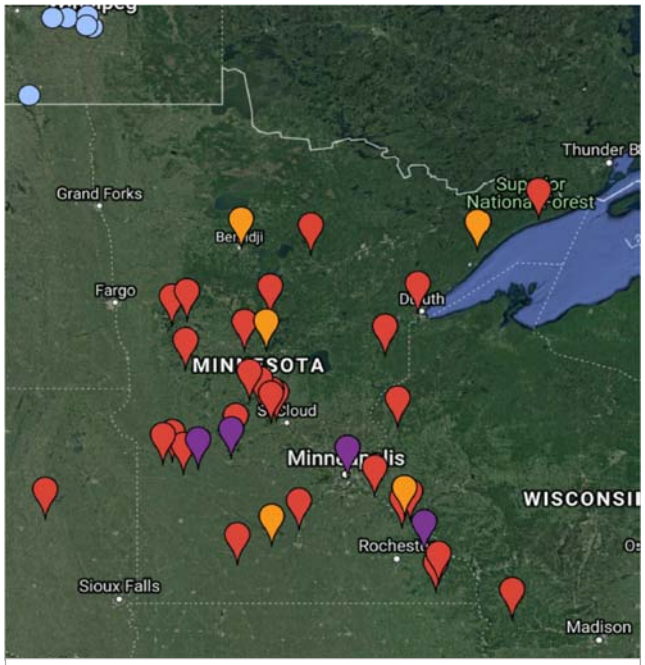
This project will conduct a thorough analysis of DWG operation, model how climatic conditions impact operations, and design DWG system components that maximize energy efficiency and environmental benefits of the production system. The project team expects to complete designs in the three-year project period. With outreach and extension efforts, the project team expects that the private sector will continue to adopt DWG technology as a winter food production system. Future DWG building and crop research will be addressed by additional state and federal grant opportunities as necessary.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Greg Schweser
Project Title: Deep Winter Greenhouses: Climate resilient food production systems
Organization: Regents of the University of Minnesota
Project Budget: $1,559,706
Project Length and Completion Date: 6/30/2023 36 months
Today's Date: 4/12/2019

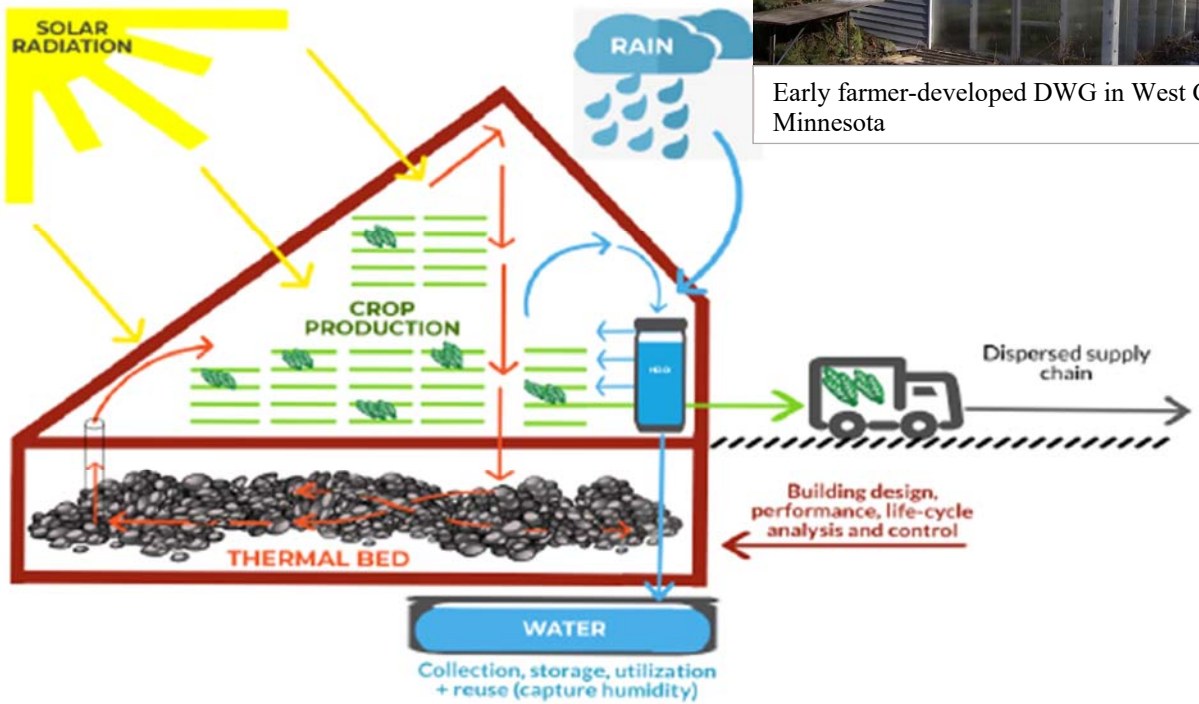
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 1,398,881	$ -	$ 1,398,881
Greg Schweser, Project Manager; $201,374 (74% salary, 26% fringe), 68% FTE each year for 3 years.			
Dr. Kathy Draeger, co-Project Manager; $74,744 (74% salary, 26% fringe), 15% FTE each year for 3 years.			
Carol Ford, DWG production expert; $54,400 (77% salary, 23% fringe), 25% FTE each year for 3 years.			
Constance Carlson, Extension supply chains; $47,923 (77% salary, 23% fringe), 20% FTE each year for 3 years.			
Joel Tallaksen, LCA researcher; $137,402 (74% salary, 26% fringe), 50% FTE each year for 3 years.			
Jane Davidson, Mech Eng professor $14,798 (74% salary, 26% fringe), 3% FTE each year for 3 years			
Graduate Student, Mechanical Engineering; Academic Term; $126,276 (53% salary, 47% fringe) 50% FTE each year for 3 years.			
Graduate Student, Mechanical Engineering; Summer Term; $26,102 (86% salary, 14% fringe) 50% FTE each year for 3 years.			
Dan Handeen, DWG architect/design; $112,308 (74% salary, 26% fringe), 38% FTE each year for 3 years.			
Graduate Student, Design; Academic Term: $52,533 (47% salary, 53% fringe) 25% FTE each year for 3 years			
Graduate Student, Design; Summer Term: $9516, (86% salary, 14% fringe) 25% FTE each year for 3 years			
Richard Graves, DWG architect/design $7,516 (74% salary, 26% fringe), 1% FTE each year for 3 years.			
Tracy Twine, Climatologist; $11,577 (74% salary, 26% fringe), 3% FTE each year for 3 years.			
Graduate Student, Soil/Water/Climate; Academic Term; $115,888 (51% salary, 49% fringe) 50% FTE each year for 3 years.			
Graduate Student, Soil/Water/Climate; Summer Term; $23,200 (86% salary, 14% fringe) 50% FTE each year for 3 years.			
John Erwin, Horticulturist $10,328 (74% salary, 26% fringe) 3% FTE each year for 3 years			
Graduate Student, Horticulture; Academic term: $117,965 (51% salary, 49% fringe) 50% FTE each year for 3 years			
Graduate Student, Horticulture; Summer term: $23,331 (86% salary, 14% fringe) 50% FTE each year for 3 years			
Dr. Kevin Linderman, Supply Chain Management; $30,763 (74% salary, 26% fringe), 3% FTE each year for 3 years.			
Dr. Karen Donohue, Supply Chain Management; $22,742 (74% salary, 26% fringe), 3% FTE each year for 3 years.			
Kate Brauman, $9,795 (74% salary, 26% fringe) 3% FTE each year for 3 years			
Linda Kingery, Extension RSDP NW Region; $37,919 (70% salary, 30% fringe), 10% FTE each year for 3 years.			
Dr. Okey Ukaga, Extension RSDP SE Region; $39,452 (75% salary, 25% fringe), 10% FTE each year for 3 years.			
Molly Zins, Extension RSDP Central Region; $30,234 (74% salary, 26% fringe), 10% FTE each year for 3 years.			
Anne Dybsetter, Extension RSDP SW Region; $30,032 (74% salary, 26% fringe), 10% FTE each year for 3 years.			
David Abazs, Extension RSDP NE Region; $30,763 (74% salary, 26% fringe), 10% FTE each year for 3 years.			
Equipment/Tools/Supplies			
Design Prototyping materials (thermal curtain material samples, deployment system prototyping, model setups for insulation systems)	$ 5,000		$ 5,000
Lifecycle analysis software and database maintenance contract	$ 4,200		$ 4,200
Cellular data plan for greenhouse hotspots in existing DWGs to monitor energy use: $600 x 3 DWGs	$ 5,400		$ 5,400
Research supplies and equipment (including soil nitrate readers, handheld plant tissue nitrate readers, horticultural lab supplies, BRICs readers, and photosynthetic readers)	$ 6,000		$ 6,000
Soil and Tissue Analysis will be conducted and shipped to the lab to determine Vitamin C and other nutrient levels in DWG crops at $1,566 per year.	$ 4,700		$ 4,700
Greenhouse soil mixes, fertilizers, seed	$ 4,500		$ 4,500
LED lights, battery, solar panel x 3 DWGs	$ 5,200		$ 5,200
Irrigation and self watering planter supplies	$ 4,000		$ 4,000
Greenhouse monitoring equipment, parts and maintenance, including the following items: 20+ channel Hobo remote monitoring systems, 50 amp AC current transformer, photosynthetic light sensor, 12 bit temperature/relative humidity sensors, soil moisture sensors, extension cables, and replacement batteries. $6000 x 3 DWGs (yr 1), $600 x 3 DWGs (yrs 2,3) for parts & maintenance	$ 21,600		$ 21,600
Day/Night Carbon dioxide monitor and controller: Hobo Tellaire 8000 data loggers @ $350 x 3 DWGs	$ 1,050		$ 1,050
Climatological monitoring equipment to procure precisely located climate data to compare to DWG growing conditions : 3 Spectrum weather stations @ $2200 ea (WatchDog 2900ET); parts	$ 8,100		$ 8,100

Printing				
Publication, documentation and dissemination: Four academic journal publications		$ 6,000		$ 6,000
Printing for extension materials		$ 800		$ 800
Travel expenses in Minnesota - all rates are based on University of Minnesota policy				
Travel of project personnel to conference hosted for project (10 people, 400 avg rt miles, 20 per diems (1st and last) x 57) + 10 hotel rooms x $151) = 4000 x .58		$ 5,170		$ 5,170
Air travel and transport from airport for 3 energy efficient controlled environment experts to present at conference hosted for project (avg $600/person x 3)		$ 1,800		$ 1,800
Travel to Controlled Environment Agriculture Conference for PI		$ 1,500		$ 1,500
Mileage for project personnel to implement research and design component of project: 7 annual trips with approx. 4,283 miles		$ 7,452		$ 7,452
Lodging for personnel to implement research and design component of project: 10 total overnight stays		$ 3,039		$ 3,039
Meals for personnel to implement research and design component of project: 4 annual 3 day trips and 3 annual 2 day trips		$ 2,391		$ 2,391
Mileage for project personnel to implement horticulture and supply chain work: 3 annual trips with approx. 1743 miles		$ 3,033		$ 3,033
Lodging for project personnel to implement horticulture and supply chain work: 3 overnight stays		$ 837		$ 837
Meals for personnel to implement horticulture and supply chain work: 2 annual 3 day trips and one annual 2 day trips		$ 1,074		$ 1,074
Mileage for project personnel to implement extension, education, and outreach work: 6 annual trips with approx. 3,370 miles		$ 5,865		$ 5,865
Lodging for personnel to implement research and design component of project: 12 total overnight stays		$ 3,996		$ 3,996
Meals for personnel to implement research and design component of project: 6 annual 3-day trips		$ 2,718		$ 2,718
Other				
Annual payments for 3 DWG farmer partners to host DWG experimental sites, care for research trials, host workshops, and participate in project activities		$ 27,000		$ 27,000
Room and service rental for Conference		$ 4,000		$ 4,000
Catering for Conference for 300 people @ $25/person to preserve continuity of the meeting. May seek to raise funds from conference participants to cover food costs.		$ 9,000		$ 9,000
Data Storage @ $1800/year (personnel computers & MN Supercomputing Institute		$ 5,400		$ 5,400
COLUMN TOTAL		$ 1,559,706	$ -	$ 1,559,706
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	**Status (secured or pending)**	**Budget**	**Spent**	**Balance**
In kind: University's Indirect costs $1,559,706 x 33%		$ 514,703	$ -	$ 514,703
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
		$ -	$ -	$ -

Early farmer-developed DWG in West Central Minnesota



Distribution of known DWGs in Minnesota



DWG operation and production system model

University of Minnesota DWG prototype

Deep Winter Greenhouse (DWG) technology was developed by pioneering vegetable farmers to grow crops in Minnesota winters without fossil fuel heat. The heavily insulated structure captures solar heat in winter through a steeply-sloped south facing glazing wall that is angled to maximize solar absorption on the coldest day of the year. That heat is drawn into an underground insulated bed of crushed rock where it is stored until needed at night or cloudy days. With design modifications, an underground cistern can capture and store nitrogen rich rainwater.

In 2016, the University of Minnesota partnered with five DWG producers throughout Greater Minnesota to build DWG prototypes that improved on initial farmer designs and demonstrated that low energy vegetable production is, in fact, possible on a small-scale in Minnesota winters.

Interest in DWGs continues to grow. With investments in DWG performance, horticultural production, market and supply chain analysis, and Extension DWG adoption can be scaled up to transform Minnesota into a year-round, carbon neutral, sustainable food production powerhouse.

Project Manager Qualifications and Organization Description

Greg Schweser is the U of MN Extension's Regional Sustainable Development Partnership statewide director of sustainable agriculture and food systems (SAFS). He works to build the capacity of community-led innovation in sustainable agriculture by connecting community innovators to education, research, and outreach resources available at the University of Minnesota. Schweser directs a statewide team of Sustainable Agriculture and Food System staff to build the capacity of food systems and small- and medium-sized farms in Minnesota by connecting locally identified need with University of Minnesota expertise. Since 2016 Schweser has been leading a Deep Winter Greenhouse initiative to investigate and commit university expertise to DWG systems, promote DWG usage, and provide outreach and education to DWG producers to help ensure sustainable and profitable operations.

University of Minnesota Regional Sustainable Development Partnerships

The Regional Sustainable Development Partnerships (RSDP) is a program of the University of Minnesota Extension that connects Greater Minnesota communities to the University in order to identify new opportunities and solve problems in sustainability. The Partnerships leverage University knowledge and seed funding with local talent and resources in four areas: agriculture and food systems, tourism and resilient communities, natural resources, and clean energy. RSDP is composed of a statewide office and five partnerships working in Greater Minnesota.