**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**

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| **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 |  |  |

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| **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* |

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| **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 |  |

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| ***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* |

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| **Activity 3 Title:** UMNExtension 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 |  |
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| **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.