

**Environment and Natural Resources Trust Fund**

# 2022 Request for Proposal

## **General Information**

**Proposal ID:** 2022-239

**Proposal Title:** Transparent Solar Panes for Agrivoltaics

## **Project Manager Information**

**Name:** Vivian Ferry

**Organization:** U of MN - College of Science and Engineering

**Office Telephone:** (612) 625-7522

**Email:** veferry@umn.edu

## **Project Basic Information**

**Project Summary:** This project will create solar panes for greenhouses that simultaneously generate electricity from sunlight and promote plant growth.

**Funds Requested:** $404,000

**Proposed Project Completion:** June 30 2024

**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?** Region(s): Metro

**What is the best scale to describe the area impacted by your work?** Statewide

**When will the work impact occur?** During the Project

## **Narrative**

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

Agrivoltaic systems are installations that co-use agricultural land for crop growth and electricity generation. Research has shown that, on a per area basis, this increases the overall efficiency of land use compared to separate installations on dedicated land. However, careful design is required to maximize the use of sunlight for both applications simultaneously.   
Common approaches rely on installing traditional solar cell arrays along field boundaries or over land that does not require a full day’s worth of solar radiation for crops which grow well in partial shade or to shelter farm animals on pastures. The solar arrays can also have a positive impact on the fields’ micro-climate, including improving water retention in soil.   
However, these approaches do not use sunlight simultaneously for both applications. The solar panel is either used to generate electricity, or to provide shade, limiting both the locations for installation and the types of crops that may be grown. Moreover, traditional solar arrays are still expensive and do not visually integrate well with landscapes. Inexpensive structures are needed that simultaneously transmit sunlight for crop growth and produce electricity on-site, blend into the rural environment, and can be installed on a variety of types of land.

**What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.**

We propose semitransparent solar panes that collect some colors of sunlight for electricity generation, but transmit others for agricultural use, allowing for true simultaneous land utilization. Photovoltaic panels do not convert all colors of sunlight to electricity at the same efficiency. Similarly, crop germination and growth can be enhanced by illumination with specific colors. Greenhouse glazing is commonly used to tailor lighting and thermal conditions.  
Our solar pane consists of a transparent, plastic sheet with nanoscale “quantum dots” embedded in the plastic, and photovoltaic devices placed at the edges. These quantum dots absorb specific colors of sunlight, transform it into colors that are efficiently converted to electricity by a photovoltaic device, and concentrate this more ideal spectrum onto the edge-mounted solar cells. This reduces the cost of electricity generation by using only a small area solar cell and eliminating the need for an expensive tracking system.  
The spectrum of the incident sunlight is also tailored for crop growth as it transmits through the solar pane. Energetic blue light, which can lead to cell damage and inhibits cell elongation, is absorbed by the solar pane. Red light, which is required for germination and plant growth of some species, is transmitted.

**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 develop solar panes that simultaneously generate clean, renewable solar electricity and promote the growth of agricultural crops. This renewable energy technology will lead to a reduction of greenhouse gas emissions, while simultaneously allowing farmers in the State of Minnesota to diversify their land use by simultaneously growing crops that thrive under red light and producing renewable electricity. This project may also lead to reduced water demands for agriculture.

## **Activities and Milestones**

### **Activity 1: Testing crop growth under transparent solar panes**

**Activity Budget:** $202,000

**Activity Description:**The solar panes contain nanometer-sized inorganic crystals called “quantum dots” that absorb sunlight and reemit it at a different color. This reemitted light is concentrated onto a small solar cell mounted at the edge of the device. Simultaneously, sunlight is transmitted through the solar pane. The efficiency of the solar cell and the radiation that reaches the crops depend on factors such as the type and quantity of quantum dots and window design. Our team will evaluate solar panes in greenhouses with silicon and copper indium sulfide quantum dots using experiments and computational models. We will create research-scale devices, test the light transmission and other optical properties, design nanostructures that direct specific colors toward the solar cell or crops, and develop models that predict the thermal impact of these solar panes on both the land underneath and the solar cell performance. Important agricultural crops, including lettuce, basil, and other bedding and potted plants will be tested with research scale devices by comparing to conventional double strength float glass. For each crop species, % seed germination, cell structure, including chloroplast number and configuration, cell size, internode length, and plant fresh/dry weights will be measured to evaluate plant growth, development, and yield.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Development of a testing protocol including controls (conventional glass panels) | October 31 2022 |
| Selection and assessment of plant species for testing including important crop species for Minnesota agriculture | October 31 2022 |
| Fabrication of small enclosures with a solar panes for plant growth | October 31 2022 |
| Evaluation of seed germination and plant growth parameters under solar panes with different transmission characteristics | June 30 2023 |

### **Activity 2: Testing scaled up solar panes**

**Activity Budget:** $202,000

**Activity Description:**As with many devices or processes, problems are encountered in scale up that are not apparent in small laboratory scale devices. In solar panes, these can be related to coating non-uniformities, agglomeration of quantum dots, etc. Building on the results of activity 1, scaled-up devices as large as 25cm x 50cm will be fabricated on a variety of substrates, including rigid substrates such as glass, Exolite, and polycarbonate, and flexible plastic sheets. The first approach will utilize a batch coating apparatus onto glass panes and the second, which may be more versatile, will involve roll-to-roll deposition onto a plastic film. The coated plastic film could then be integrated onto an existing structure. For both options, a dispersion of quantum dots in a polymer solution will be prepared and deposited onto a substrate. These scaled-up devices can be used for major crops. For these larger scale devices, conditions will be determined that optimize both plant growth and photovoltaic electricity generation. Optimal plant growth for each crop will be determined, based on growth parameters such as the number of leaves, plant height, plant width, leaf length/width, number of leaves to flowering, visible bud date, and anthesis.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Optimize quantum dot/polymer solutions for large scale coating processing | August 31 2023 |
| Testing of coating methods for uniform deposition and curing over large areas | September 30 2023 |
| Optimization of the coating process for rigid glass and plastic sheets | October 31 2023 |
| Testing and comparison of plant growth using scaled-up solar panes | December 31 2023 |
| Optimization of plant growth and photovoltaic electricity generation | June 30 2024 |

## **Project Partners and Collaborators**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Organization** | **Role** | **Receiving Funds** |
| Uwe Kortshagen | University of Minnesota | Uwe Kortshagen is Professor of Mechanical Engineering at the University of Minnesota, and holds the Ronald L. and Janet A. Christenson Chair in Renewable Energy. Professor Kortshagen is an expert in the synthesis of silicon quantum dots with nonthermal plasmas. His group wil synthesize quantum dots and fabricated solar panes. | Yes |
| Lorraine Francis | University of Minnesota | Lorraine Francis is Professor of Chemical Engineering and Materials Science at the University of Minnesota. Professor Francis’ research interests include coating processing, microstructure and stress development in coatings, and development of processes and materials for printed electronics. She will develop large scale coating processes for the solar panes. | Yes |
| Neil Anderson | University of Minnesota | Neil Anderson is a Professor of Flower Breeding/Genetics in the Department of Horticultural Science. He is a recognized expert in greenhouses and sustainable greenhouse production systems. His role in the project will be plant production using the solar panes to determine whether plant growth is optimized. | 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 be funded?**The panes will be tested in greenhouses for their effects on plant growth. At the conclusion of the project, the investigators will seek industrial partners who are interested in commercializing these coatings for greenhouse applications, as either replacements for glass/plastic panes or as retrofit coatings. The investigators will also apply to other federal funding agencies such as the Department of Energy at the completion of this project for additional research support.

## **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:** Vivian Ferry

**Job Title:** Associate Professor

**Provide description of the project manager’s qualifications to manage the proposed project.**Vivian Ferry is an Associate Professor of Chemical Engineering & Materials Science at the University of Minnesota. She has published more than 50 research papers and given over 70 invited talks. Professor Ferry has directed research on over $2M worth of funding, and has received numerous awards recognizing her contributions to renewable energy, including the National Science Foundation CAREER award, the American Physical Society Ovshinsky Sustainable Energy Fellowship, and the SPIE Early Career Achievement Award. In 2016 she was named one of Technology Review’s 35 Innovators under 35 for her work on photovoltaics. She leads a research group with expertise in the optical properties of nanoscale materials, and performs both experimental and computational research.

**Organization:** U of MN - College of Science and Engineering

**Organization Description:**The University of Minnesota offers world-class infrastructure for this project. The luminescent silicon crystal synthesis will be performed in Kortshagen’s laboratory. This lab is one of the best equipped plasma technology laboratories in the world. Solar pane device fabrication will be performed in Professor Ferry’s laboratory. Professor Ferry’s laboratory also has numerous unique modeling techniques to predict the performance of the solar panes in outdoor installations, and access to the Minnesota Supercomputing Institute, the University of Minnesota’s principle center for computational research. The Coating Process and Visualization (CPV) Lab is a unique academic facility with equipment for coating and printing, visualization and characterization. The CPV Lab is the primary lab of the Coating Process Fundamentals Program, a research program of the Industrial Partnership for Research in Interfacial and Materials Engineering (IPRIME). The Plant Growth Facilities has state-of-the-art, computer-controlled greenhouses for testing the material types generated in this grant.  
In addition, the team has access to a large number of shared materials characterization instruments at the University of Minnesota Materials Characterization Facility (“CharFac,” http://www.charfac.umn.edu/), including a small angle X-ray scattering facility, and an electron microscopy center. Several machine shops are also available at

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified Staff?** | **$ Amount** |
| **Personnel** |  |  |  |  |  |  |  |  |
| Project Manager - Faculty Director |  | Direct research progress and project reporting. (approved fringe rate 36.5% rate) |  |  | 26.7% | 0.04 |  | $7,830 |
| 3 Faculty Investigators |  | Direct research efforts. (approved fringe rate 36.5% rate) |  |  | 26.7% | 0.12 |  | $36,929 |
| 3 Research Assistants |  | Perform research on solar pane fabrication and characterization and plant growth experiments. (approved fringe rate: 19.90% for health insurance and 21.06/hour for tuition. Students will not take summer classes.) |  |  | 42.1% | 6 |  | $318,531 |
|  |  |  |  |  |  |  | **Sub Total** | **$363,290** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Tools and Supplies | Materials and supplies | Materials for solar pane manufacturing, plant growth experiments, including, chemicals, gases, coating supplies, seeds, light sources |  |  |  |  | $20,710 |
|  | Tools and Supplies | Characterization facility | Fees to characterize materials such as user fees for electron microscopes, etc. |  |  |  |  | $20,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$40,710** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Acquisitions and Stewardship** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel In Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel Outside Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Printing and Publication** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Other Expenses** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
|  |  |  |  |  |  |  | **Grand Total** | **$404,000** |

### **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** | **-** |

## **Attachments**

### **Required Attachments**

#### ***Visual Component***

File: [87623ce1-17d.pdf](https://lccmrprojectmgmt.leg.mn/media/map/87623ce1-17d.pdf)

#### ***Alternate Text for Visual Component***

The attached figure shows the general concept, where transparent panes containing quantum dots are embedded in a greenhouse. Incident sunlight is both captured and converted to electricity and transmitted to promote plant growth....

### **Optional Attachments**

#### ***Support Letter or Other***

|  |  |
| --- | --- |
| **Title** | **File** |
| SPA | [40848429-efb.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/40848429-efb.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?**   
 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