Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 190-EH**

Sustainable Solar Energy from Agricultural Plant Byproducts

Category: H. Proposals seeking $200,000 or less in funding

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

Total Project Budget: $ 185,018

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

Producing new materials from regional plant byproducts for renewable solar energy. This project engages many students in environmental research; this homegrown technology will ultimately provide affordable energy to Minnesota families.

Name: Ted Pappenfus

Sponsoring Organization: U of MN - Morris

Title:

Department: Division of Science and Mathematics

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Morris MN 56267-2132

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Refining of agricultural play byproducts to produce conductive materials for printed organic solar cells will help develop inexpensive, clean, renewable solar power while providing research training for Minnesota students.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Sustainable Solar Energy from Agricultural Plant Byproducts

I. PROJECT STATEMENT

Envision every house in Minnesota capable of producing renewable energy using plastics made from agricultural byproducts such as corncobs. The objective of this project is to take this idea from the benchtop to the rooftop by producing sustainable chemicals from agricultural byproducts that can be used in organic photovoltaics (OPVs). OPVs (i.e., organic solar cells) are a promising renewable energy technology driven by their capability to be printed across large areas using roll-to-roll processing techniques–thus, creating the vision of covering every roof and other suitable building surface with organic photovoltaics at extremely low cost.

At the heart of every OPV is an organic (i.e., carbon-based) material that absorbs sunlight and transfers its energy within the device to produce useful electrical current. Although scientists across the planet have made many of these light-harvesting materials with good solar cell efficiencies, the vast majority of these organic materials are petroleum based. As we have a finite supply of petroleum on the planet, it is imperative that we find sustainable routes to make materials. One attractive chemical for the production of organic photovoltaic materials is furfural – an organic compound produced from a variety of agricultural byproducts, including corncobs and corn stover. As part of a collaboration between the Morris and Twin Cities campuses of the University of Minnesota, we have found that furfural functions well as a petroleum substitute in small molecules. This project will utilize this technology for making polymers that link many small molecules in long chains to make plastics. These plastics can then be used for the fabrication of printed organic photovoltaics that will lead to a more sustainable, low-cost, renewable energy source in Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Preparing and testing bio-based plastics for organic solar cells;* **Budget:** $101,760

The objective of this activity is to develop furfural-based plastics that will function as light-absorbing materials in organic photovoltaics. The first step will be to prepare small molecules that contain furfural. These small molecules (or monomers) will then be polymerized to make the desired plastics. Fully petroleum-based plastics will also be prepared for control purposes. The physical properties of the plastics will be evaluated using a variety of analytical methods at the University of Minnesota, Morris and St. Catherine University. The performance of the plastics will be evaluated in small-scale organic photovoltaics (in collaboration with the University of Newcastle) and the results of these initial devices will help guide second-generation furfural plastics. The synthesis of the best performing plastic(s) will then be explored at increased scale as candidates for large area organic photovoltaics. Results of the project will be readily available to LCCMR committee members and officials and will also be disseminated more broadly to the scientific community.

Outcome	Completion Date
1. Prepare initial corn-based sustainable molecules and plastics and compare to non-sustainable (petroleum-based) materials	*Dec. 31, 2019*
2. Fabricate and test initial solar cell devices using materials prepared in Outcome 1.	*May 31, 2020*
3. Prepare improved corn-based sustainable molecules and plastics and compare to non-sustainable (petroleum-based) materials	*Dec. 31, 2020*
4. Fabricate and test a second round of solar cell devices using improved materials prepared in Outcome 3	*May 31, 2021*
5. Scale-up production of corn-based sustainable molecules and plastics and compare to non-sustainable (petroleum-based) materials	*June 30, 2022*

Activity 2: Production and quantification of corn-based furfural as a sustainable chemical; **Budget:** $83,258

The objective of this activity is to find improved methods for the production and quantification of furfural from agricultural biomass (where quantification refers to determining how much furfural is produced in a given chemical reaction). The first step will be to find cheap and rapid methods to quantify furfural using affordable instruments and readily available smartphones. The quantitative work will take place as a collaborative effort between undergraduate and high school students and will serve as a great introduction to this overall project for the students. The second step will involve the development of advanced quantification methods for furfural using high performance liquid chromatography (HPLC) which will provide more detailed results in order to confirm the validity of the simple methods from Outcome 1. Once quantification methods have been established, furfural production will be developed on the benchtop scale using simple sugars as they are the basic components of biomass. Optimized methods will then be applied to biomass samples. The bulk of the work for Outcomes 2-4 will take place on the Morris and St. Catherine campuses.

Outcome	Completion Date
1. Develop simple quantification methods of furfural using spectroscopy and smartphones	*Aug. 31, 2020*
2. Develop advanced quantification methods of furfural using chromatography	*Dec. 31, 2020*
3. Production of furfural from simple sugars using solid-acid catalysts	*May 31, 2021*
4. Production of furfural from biomass using solid-acid catalysts	*June 30, 2022*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Dr. Daron Janzen	**Associate Professor of Chemistry**	**St. Catherine University, St. Paul, MN**	**Analysis of materials; solid-state syntheses**
Mr. Zachary Boser	**Science Instructor**	**Kimball High School, Kimball, MN**	**Furfural Detection; Mentor for Students**
Mr. Michael Maudal	**Science Instructor**	**Red Wing High School, Red Wing, MN**	**Furfural Detection; Mentor for Students**

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Professor Paul Dastoor	**Professor of Physics**	**University of Newcastle, New S. Wales, Australia**	**Organic Solar Cell Device Fabrication and Testing**

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

At the conclusion of the project, both Activities 1 and 2 will continue. Funds will be sought from the Minnesota Corn Grower's Association to scale up furfural production methods developed as part of this project. Additional funding will be sought (from the Department of Energy and/or Xcel Energy's Renewable Development Fund) for a large area photovoltaic test site on the UMM campus using these corn-based plastics. Prof. Dastoor has two organic photovoltaic test sites currently operating in Australia; an additional site in a climate such as MN would provide valuable data. Long term, we will seek funding from the Gates Foundation to construct a printing center in MN to deliver corn-based organic photovoltaics to low income Minnesota families.

V. TIME LINE REQUIREMENTS:

This project is planned for 3 years beginning on July 1, 2019 and ending on June 30, 2022. Activities 1 and 2 will be performed concurrently and will be completed with the milestones explained above.

2019 Proposal Budget Spreadsheet

Project Title: Sustainable Solar Energy from Agricultural Plant Byproducts

IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

BUDGET ITEM (See "Guidance on Allowable Expenses")	**AMOUNT**
Personnel (U of MN, Morris Campus)**:**	**$ 89,675**
Professor Ted Pappenfus, Project Manager: 18 % FTE YR 1-3 (66% salary; 34% fringe) *(1.5 mo. summer salary in YR 1-3; 2 credit fall semester release to work with undergraduates in YR 1-3)*	80,459
Undergraduate Research Assistant: 21% FTE YR 1-3 (100% salary) *(8 weeks; 32 hrs/wk @$12/hr)*	9,216
Professional/Technical/Service Contracts:	**$ 45,163**
Associate Professor Daron Janzen, Co-PI (St. Catherine Univ.): 11% FTE YR 1-3 (83% salary; 17% fringe) *(1.0 mo. summer salary in YR 1-3)*	26,353
Undergraduate Research Assistant (St. Catherine Univ.): 21% FTE YR 1-3 (100% salary) *(8 weeks; 20 hrs/wk; @$12.25/hr(2019) $13.25/hr(2020), $14.25/hr(2021))*	6,360
Summer Contracts for High School Instructors ($3,000/summer in YR 1 and 2 for each of two instructors) *(5 weeks @20 hrs/wk)*	12,000
Contract Analytical Services for Analysis of Samples Produced in the Project *(5 samples per year @$30/sample)*	450
Equipment/Tools/Supplies:	**$ 47,180**
Two Benchtop Ball Mills for Solid State Reactions ($10,590 ea.); One for use on the Morris Campus; One for use at St. Catherine Univ. This equipment will be used during its useful life for the research described in this proposal and for similar environmental research after this specific project has ended.	21,180
Lab materials, chemicals and lab supplies for project activities: (a) $6,000/yr for 3yrs for UMM; (b) $2,000/yr for 3 yrs for St. Catherine U; and (c) $1,000 for each high school in YR 1	26,000
Travel:	**$ 3,000**
Domestic, in-state travel for Project Manager Pappenfus to travel to Project Partners ($1,000/yr) *(Travel will be reimbursed per University of MN travel policies)*	3,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 185,018

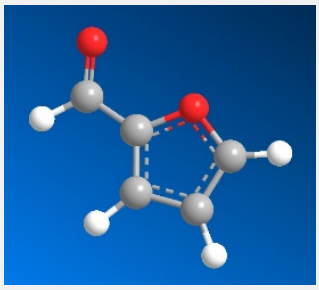
V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: UMM Chemistry Undergraduate Research Fund: Funds will be available to cover a second undergraduate student in YR 1-3 at UMM ($3,072/yr) plus housing for both students in each summer ($500/summer for each student)	$ 12,216	*Secured*
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period: The 54% in foregone federally negotiated ICR funding constitutes a portion of the University of Minnesota, Morris's cost share to the project.	$ 75,349	*Secured*
Past and Current ENRTF Appropriation:	N/A	
Other Funding History:	N/A	

Sustainable Solar Energy from Agricultural Plant Byproducts

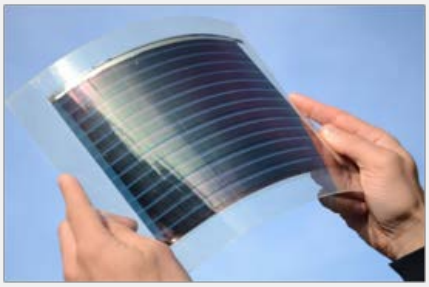
Project Overview:

Agricultural Biomass →



Chemical from Biorefining Corncobs →

Conducting Plastic using Biorefined Chemical ↓



Printed Organic Solar Cell using Bio-based Plastic

Project Impacts:

Project Will Help Develop:

***Inexpensive, Clean, Renewable Energy for Minnesota Families**

Taking the project from the benchtop to the rooftop.

Impacts on Students:

***Opportunity for Environmental Research and Training in the Physical Sciences**

Approx. 40 high school and college students will be directly involved in the project.

Project Manager Qualifications and Organization Description

Ted Pappenfus, Project Manager

Ted Pappenfus is a Horace T. Morse Distinguished University Professor of Chemistry at the University of Minnesota, Morris. He received his Ph.D. in Chemistry in 2001 from the University of Minnesota, Twin Cities and his postdoctoral work also took place on the Twin Cities campus in the Department of Chemical Engineering and Materials Science. PI Pappenfus has a strong track record of supervising, mentoring and training undergraduate students and has worked with over 80 undergraduate students in his fourteen years at UMM. Pappenfus also has worked with high school students on research projects as part of the American Chemical Society Project SEED program which serves economically disadvantaged students. Pappenfus has collaborated with many scientists across the planet in the area of materials chemistry which has resulted in more than 45 peer-reviewed publications. His research has been supported by a variety of sources including the National Science Foundation and American Chemical Society Petroleum Research Fund. For his efforts in sustainability, Pappenfus was awarded the ACS-CEI Award for Incorporation of Sustainability into Chemistry Education in 2012.

Organization Description

The University of Minnesota, Morris (UMM) is a distinctive campus of the University of Minnesota, located 160 miles west of the Minneapolis-St. Paul metropolitan area. Students are provided with a quality education comparable to, but at a lower cost than, most private liberal arts colleges in the United States, including access to ample opportunities to complete meaningful research. Established as a solely undergraduate liberal arts campus in 1963, the site of UMM has a deep history, first serving as a American Indian boarding school from the late 1800s to 1909 and then as the West Central School of Agriculture from 1910-1963.

The institution is committed to sustainability through policies and practices that are not only embedded throughout campus, but also extend to the local rural communities. UMM has commitments and investments devoted to sustainability in a variety of areas: renewable energy; local and sustainable food and healthy eating; community outreach and education; and conservation.

As one of the nation's top public liberal arts colleges, UMM serves a broad range of students and provides them with an intellectually rigorous education. Despite its rural location, UMM maintains the highest percentage of students of color (24%) of any campus in the University of Minnesota system. Similarly, we have a high number of students with financial need (31% are from families whose taxable income did not exceed 150% of federal poverty guidelines) and a large number of first-generation college students (38%).

UMM is organized into four divisions: Education, Humanities, Science and Mathematics, and Social Sciences. The Division of Science and Mathematics includes the seven disciplines of Biology, Chemistry and Biochemistry, Computer Science, Geology, Mathematics, Physics, and Statistics. Division classrooms, teaching and research laboratories, computer facilities, and faculty offices are housed in a science complex consisting of three wings, two of which were newly constructed in 2000 and the other completely renovated in 2002. The Science and Math Division's strengths reflects those of the institution: intellectually gifted students, a faculty dedicated to teaching, and an emphasis on collaborative research involving undergraduate students. In addition, students have ready access to the instrument labs and the high-level instrumentation for their course-related and research activities.