Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2019 ENRTF Work Plan (Main Document)

Today's Date: February 10, 2019

Date of Next Status Update Report: March 1, 2020

Date of Work Plan Approval:

Project Completion Date: June 30, 2022

Does this submission include an amendment request? No

PROJECT TITLE: Sustainable Solar Energy from Agricultural Plant Byproducts

Project Manager: Ted Pappenfus

Organization: Morris Campus (Regents of the University of Minnesota)

College/Department/Division: Division of Science and Mathematics

Mailing Address: 600 E 4th Street

City/State/Zip Code: Morris, MN 56267

Telephone Number: 320-589-6340

Email Address: pappe001@morris.umn.edu

Web Address: http://cda.morris.umn.edu/~pappe001/

Location: Statewide

Total Project Budget: $185,000

Amount Spent: $0

Balance: $185,000

Legal Citation: M.L. 2019, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:

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 biomass 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. OVERALL PROJECT STATUS UPDATES:

First Update March 1, 2020

Second Update September 1, 2021

Third Update March 1, 2021

Fourth Update September 1, 2022

Fifth Update March 1, 2022

Final Report between project end (June 30) and August 15, 2022

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1 Title: Preparing and testing bio-based plastics for organic solar cells
Description: 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 devices (organic photovoltaics in collaboration with the University of Newcastle or organic transistors in collaboration with the University of Málaga) 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.

ACTIVITY 1 ENRTF BUDGET: $101,760

Outcome	Completion Date
1. Prepare initial sustainable molecules and polymers using mechanochemical and DArP methods; compare the materials to non-sustainable (petroleum-based) materials	*Dec. 31, 2019*
2. Fabricate and test initial devices using materials prepared in Outcome 1 (approximately two new polymers will be tested).	*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 devices using improved materials prepared in Outcome 3 (approximately three additional new polymers will be tested).	*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*

First Update March 1, 2020

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ACTIVITY 2 Title: Production and quantification of corn-based furfural as a sustainable chemical
Description: 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 3D printed colorimeters. 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 utilize 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 3D printed spectrometers. 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. The bulk of the work for Outcomes 2-4 will take place on the Morris and St. Catherine campuses.

ACTIVITY 2 ENRTF BUDGET: $83,240

Outcome	Completion Date
1. Develop simple quantification methods of furfural with visible spectroscopy using 3D printed colorimeters	*Aug. 31, 2020*
2. Use advanced quantification methods (HPLC) to test the validity of the simple quantification methods of furfural developed in Outcome 1	*Dec. 31, 2020*
3. Production of furfural from simple sugars using solid-acid catalysts	*May 31, 2021*
4. Optimize production of furfural from simple sugars using solid-acid catalysts	*June 30, 2022*

First Update March 1, 2020

Second Update September 1, 2021

Third Update March 1, 2021

Fourth Update September 1, 2022

Fifth Update March 1, 2022

Final Report between project end (June 30) and August 15, 2022

IV. DISSEMINATION:

Description: 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. Results of the project will be presented locally at the various respective institutions. Data, results, and samples will also be shared across institutions. Undergraduate students will present results at national meetings and completed project activities will be submitted for publication in peer-reviewed scientific journals when appropriate.

The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

First Update March 1, 2020

Second Update September 1, 2021

Third Update March 1, 2021

Fourth Update September 1, 2022

Fifth Update March 1, 2022

Final Report between project end (June 30) and August 15, 2022

V. ADDITIONAL BUDGET INFORMATION:

A. Personnel and Capital Expenditures

Explanation of Capital Expenditures Greater Than $5,000: Two Benchtop Ball Mills for Solid State Reactions ($10,590 ea.); One for use on the Morris Campus; One for use at St. Catherine University. 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.

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours for entire duration of project: 2226	Divide total personnel hours by 2,080 hours in 1 yr = TOTAL FTE: 1.1

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

Enter Total Estimated Contract Personnel Hours for entire duration of project: 400	Divide total contract hours by 2,080 hours in 1 yr = TOTAL FTE: 0.2

VI. PROJECT PARTNERS:

A. Partners outside of project manager's organization 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 outside of project manager's organization 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**
Professor Juan Casado	**Professor of Chemistry**	**University of Málaga, Málaga, Spain**	**Organic Transistor Device Fabrication and Testing**

VII. 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.

VIII. REPORTING REQUIREMENTS:

- Project status update reports will be submitted March 1 and September 1 each year of the project
- A final report and associated products will be submitted between June 30 and August 15, 2022

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet (N/A)
D. Acquisition, Easements, and Restoration Requirements (N/A)
E. Research Addendum

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2019 Budget Spreadsheet
Legal Citation:
Project Manager: Ted Pappenfus
Project Title: Sustainable Solar Energy from Agricultural Plant Byproducts
Organization: Morris Campus (Regents of the University of Minnesota)
Project Budget: $185,000
Project Length and Completion Date: 3 Years, June 30, 2022
Today's Date: February 10, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits): University of MN, Morris	$ 101,675	$ -	$ 101,675
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)			
Undergraduate Research Assistant: 21% FTE YR 1-3 (100% salary) (8 weeks; 32 hrs/wk @$12/hr)			
Summer Contracts for High School Instructors ($3,000/summer in YR 1 and 2 for each of two instructors) (5 weeks @20 hrs/wk)			
Professional/Technical/Service Contracts: St Catherine University	$ 38,713	$ -	$ 38,713
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)			
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))			
Lab materials, chemicals and lab supplies for project activities: $2,000/yr for 3 yrs for St. Catherine U			
Equipment/Tools/Supplies: University of MN, Morris	$ 20,432	$ -	$ 20,432
Lab materials, chemicals and lab supplies and analytical services for sample analysis for project activities: (a) $6,144/yr for 3yrs for UMM; (b) $1,000 for each high school in YR 1			
Capital Expenditures Over $5,000	$ 21,180	$ -	$ 21,180
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.			
Travel expenses in Minnesota: University of MN, Morris	$ 3,000	$ -	$ 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)			
COLUMN TOTAL	$ 185,000	$ -	$ 185,000

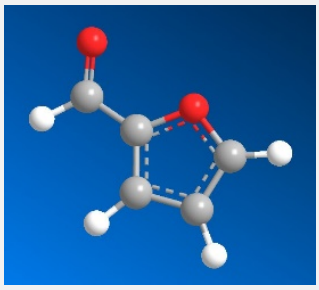
OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: UMM Chemistry Undergraduate Research Fund: Funds will be available to cover a second undergraduate student in YR 1-3 at UMM ($3,072/yr) plus housing for both students in each summer ($500/summer for each student)	Secured	$ 12,216	$ -	$ 12,216
State: N/A	N/A	$ -	$ -	$ -
In kind: The 54% in foregone federally negotiated ICR funding constitutes a portion of the University of Minnesota, Morris's cost share to the project.	Secured	$ 88,463	$ -	$ 88,463

PAST AND CURRENT ENRTF APPROPRIATIONS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Current appropriation: N/A	N/A	$ -	$ -	$ -
Past appropriations: N/A	N/A	$ -	$ -	$ -

Sustainable Solar Energy from Agricultural Plant Byproducts

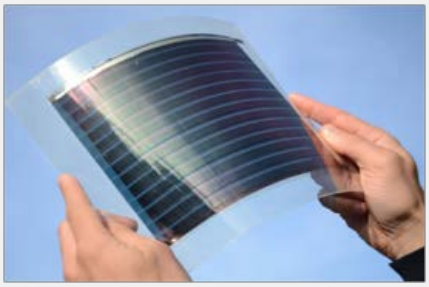
Project Overview:

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.