Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

Project Title: **ENRTF ID:** **124-E**

Greenhouse Gas Reduction through Forest Based Bio-Chemicals

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

Total Project Budget: $ 199,280

Proposed Project Time Period for the Funding Requested: 2 Years, July 2014 - June 2016

Summary:

We will reduce greenhouse gas emissions and enhance carbon sequestration by replacing petroleum based fuels and chemicals with forest based materials, providing additional revenue streams for paper and forest industry.

Name: Ulrike Tschirner

Sponsoring Organization: U of MN

Address: 203 Kaufert Lab, 2004 Folwell Ave
St. Paul MN 55108

Telephone Number: (612) 624-8798

Email ulrike@umn.edu; awards@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

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

PROJECT TITLE: Greenhouse gas reduction through forest based bio-chemicals

I. PROJECT STATEMENT

The overall goal of this project is to reduce greenhouse gas emissions and enhance carbon sequestration by replacing petroleum based fuels and chemicals with forest based biofuels and bio-chemicals, providing additional revenue streams for the struggling paper and forest industry while promoting management of a healthy forest ecosystem in Minnesota.

We propose to conduct both experimental, techno-economic process evaluations and environmental assessment of forest based bio-chemicals, specifically extracting and converting hemicellulose (wood derived sugars) to replace fossil derived fuels and chemicals in Minnesota.

Our approach involves:

(1) pre-extraction of hemicelluloses (sugars) from wood chips prior to pulping.
(2) maintaining the same yield of high quality fibers for subsequent paper manufacturing.
(3) hemicelluloses recovery and determination of best suited bio-chemicals from hemicelluloses. including biofuels, polymeric barrier films (replacing Polyethylene), adhesive or binders (replacing latex).
(4) techno-economic process feasibility evaluation of the overall system .
(5) environmental assessment of the overall process and products best suited for Minnesota mills, including assessment of greenhouse gas emission reductions and carbon reductions.

Minnesota's forest industry including pulp and paper, a major contributor to Minnesota's economy, is currently under severe economic pressure. Mill closures and layoffs resulting in loss of high paying manufacturing job contribute greatly to the economic decline in several areas of greater Minnesota. Minnesota's logging operations are down by more than 60%. There even has been some concern about forest land being repurposed for corn. We are proposing to recover an underutilized forest based material, hemicelluloses, a wood based sugar, currently being burnt, from existing pulping processes. The recovered sugars have the potential to be used for number of products, effectively replacing petroleum or corn based materials. This approach not only provides much needed additional revenue for the industry, but also promotes increased use of forest based biomass and therefore increased carbon sequestration (increased consumption of CO_2 by increased forest plantings). It will also help to mitigate greenhouse gas emissions by replacing petrochemicals with bio-chemicals.

Currently approximately 5,000 tons of dry pulp wood per day are processed to papermaking fiber in Minnesota's Kraft pulping process. Wood consists of three main components, cellulose, hemicellulose and lignin. In the process of producing papermaking fiber hemicelluloses and lignin are partially dissolved (in the cooking liquor, called black liquor) and burned. As the heating value of hemicelluloses is very low, combustion is not an effective use of these sugars. Instead of burning, we propose to recover hemicellulose sugars prior to pulping through a simple extraction step. Hemicelluloses have several potential carbon neutral high value application options. For example, the hemicellulose can be concentrated and shipped to existing corn based ethanol plants, or hemicellulose can be used in paper coating as a barrier film or "binder"; it can be added to the paper fiber to increase paper strength, replacing other petroleum based strength additives.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: *Optimization of Hemicelluloses sugar extraction and pulping of fibers for paper.* **Budget $51,506**

Extraction of hemicelluloses from wood chips followed by subsequent pulping; optimization of hemicelluloses yield, quality of pulp, harvesting of high quality hemicelluloses (membrane filtration). Data collection for analysis

Outcome	Completion Date
1. Optimization of pre-extraction or hemicellulose (high sugar yield) from chips	*Year 1, Quarter 2*
2. Membrane filtration of hemicellulose (low cost, high yield), clean product	*Year 1, Quarter 2*
3. Optimize pulping of remaining chips (high pulp yield, maintain pulp fiber quality)	*Year 1, Quarter 3*

Activity 2 : *Utilization of hemicelluloses for high value application* **Budget :$ 67,579**

Determination of highest value application for harvested hemicelluloses. We will test use of hemicelluloses to replace polyethylene coatings in moisture barriers (packaging), replace corn in ethanol production, replace latex in paper coating, replace fossil derived additives in strength applications in paper and others if appropriate.

Outcome	Completion Date
1. Determine parameters important for Hemicellulose use in ethanol generation	*Year 1, Quarter 4*
2. Demonstrate potential use of hemicelluloses for other biofuels (e.g. butanol)	*Year 1, Quarter 4*
3. Develop paper coating options using hemicellulose (barrier film, binder)	*Year 2, Quarter 1*
4. Evaluate use of hemicelluloses as strength additive in paper	*Year 2, Quarter 1*

Activity 3: *Techno-economic, process and environmental assessment* **Budget $ 80,194**

Conduct technical and economic analysis and environmental assessment (TEEA) (including greenhouse gas emission reductions and carbon reduction) to evaluate the feasibility of hemicellulose extraction, conversion and integration of the new process into existing Minnesota forest industry .

Outcome	Completion Date
1. Development of detailed process engineering analysis for hemicelluloses extraction, separation, purification and conversion to biofuels or other applications	*Year 2 Quarter 2*
2. Integration with existing pulp and paper operations using WinGEMS and ASPEN Plus	*Year 2 Quarter 3*
3. Evaluation of technical and economical feasibility and optimization of process as well as evaluation of environmental impact including GHG emission reductions of overall system	*Year 2 Quarter 4*

III. PROJECT STRATEGY

A. Project Team/Partners

Overall project management, including planning, execution, analysis of the results and submission of interim reports and final report will be the responsibility of the PI (Tschirner, Dept. of Bioproducts and Biosystems Eng., University of Minnesota). Dr. Tschirner has a strong background in biomass conversion, Ph.D. lignin chemistry; industry experience in pulping and bleaching and academic research experience in various aspects of biomass conversion. PI will supervise hemicellulose pre-extraction processes, analytical procedures and fermentation process. Dr. Ramaswamy Dept. of Bioproducts and Biosystems Eng., University of Minnesota, holds graduate degrees in Chemical Engineering and Paper Science and Engineering and will supervise the studies focused on separation and purification technologies and the techno-economic feasibility analysis and environmental assessment of the overall system.

B. Timeline Requirements

We are proposing a 2 year project. Due to a former grant through IREE (Initiative on Renewable Energy and the Environment) we were able to establish baseline parameters for hemicelluloses pre-extraction. Year one of this project will be used to optimize hemicellulose pre-extraction and membrane separation processes (harvesting of clean hemicelluloses), as well as the exploration of hemicellulose conversion options, including ethanol, butanol, paper coating or barrier films, and adhesives. The process engineering and techno-economic analysis and environmental assessment will be mostly conducted in year 2 and will use data collected in Activity 1 and 2 from above as well as use existing pulp mill data.

C. Long-Term Strategy and Future Funding Needs

Following successful development of the technology, the next step will be pilot scale demonstration and then commercial implementation in an existing pulp and paper mill in Minnesota. These steps will have to be financed by these industries. We will work closely with Minnesota paper mills, biofuels producers and ethanol plants to ensure successful commercial implementation.

2014 Detailed Project Budget

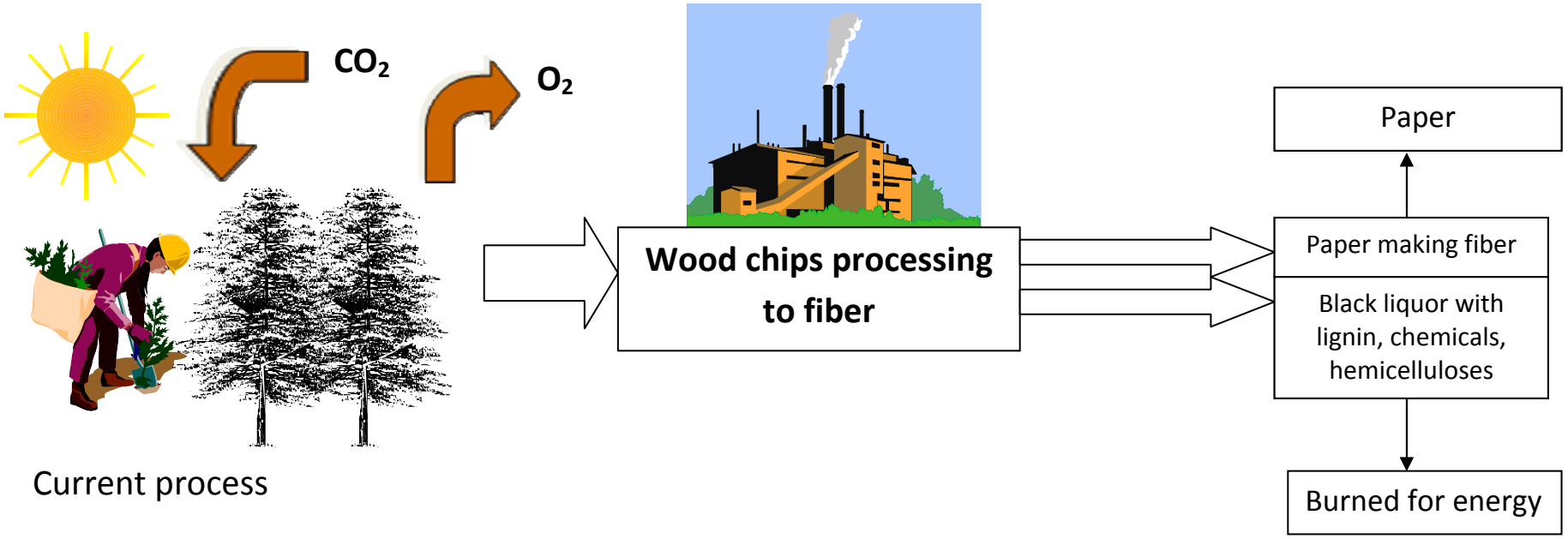
Project Title: Greenhouse gas reduction through forest based bio-chemicals

IV. TOTAL PROJECT REQUEST BUDGET 2 years

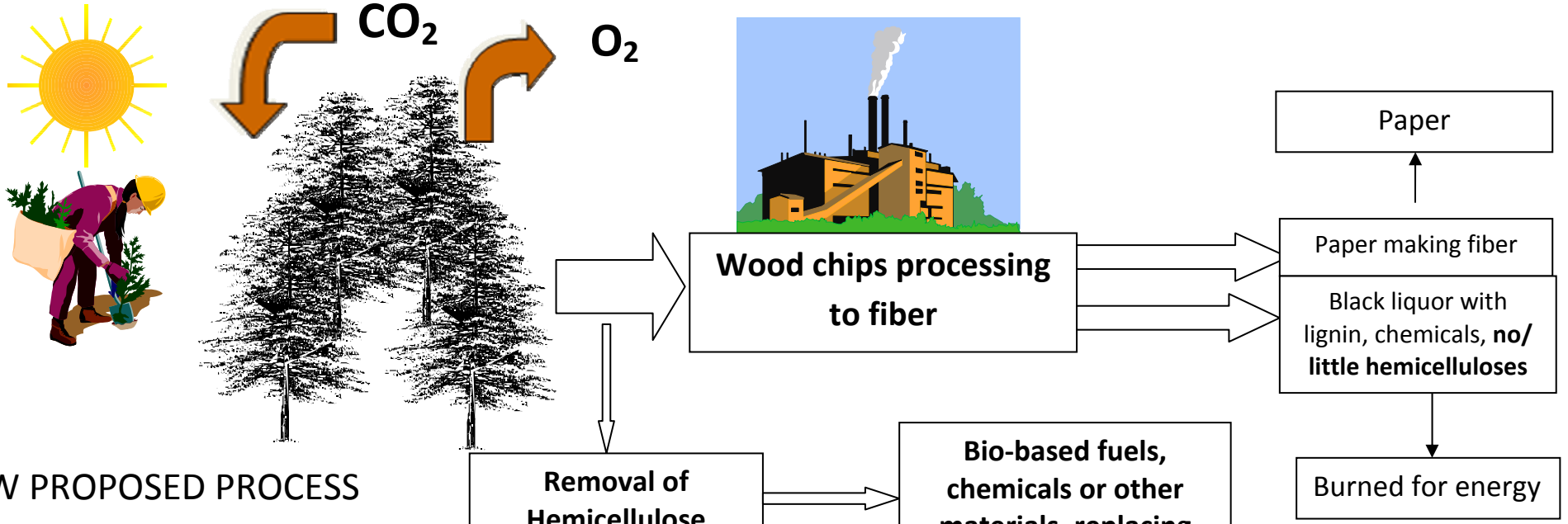
BUDGET ITEM	AMOUNT
Personnel:	
PI Tschirner 1 month summer salary year 1 and 2 (8%) including fringe at 33.6%, Tschirner is on a 9 month only appointment. Responsibilities include: management, hemicellulose extraction, pulping, analytical procedures, hemi applications	$ 32, 908
Post-doc researcher (H. Huang) 100% salary and fringe at 33.6% in year 2 ; responsibilities techno-economic analysis (detailed computer modeling of process and process variables, optimization of process), analysis of environmental impact of process changes on green house gas emission, including Life Cycle Assessment), assist in dissemination efforts (seminars, presentations to mills)	$72,287
Undergraduate Research Assistants (3), combined approximately 700 hours to help with lab experiments and data collection	$8,721
Post-doc researcher (J. Ai) 100% salary and fringe at 33.6% year 1 and 3 month in year 2, will perform sugar extraction, analysis, pulping, development of applications replacing petrochemicals with this forest based biomaterial	$75,364
Equipment/Tools/Supplies:	
HPLC columns for sugar analysis (2 total @ 1,000 each)	$2,000
Membranes to separate hemicellulose from liquor, filter paper, NaOH, solvents ($2,000 year 1 and $1,000 year 2	$3,000
Acquisition (Fee Title or Permanent Easements):	N/A
Travel: Travel to Minnesota forest industry for discussion, to collect relevant data and start dissemination efforts	$1,000
Additional Budget Items: Process modeling and analysis software (WINGEMs and ASPEN plus) and Life Cycle Assessment database licenses ($2000/year)	$4,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$199,280

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period:	N/A	*N/A*
Other State $ Being Applied to Project During Project Period:	N/A	*N/A*
In-kind Services During Project Period: University of Minnesota In-Kind cost recovery(@ 52%) waiver	$ 103,626	*secured*
In kind,1% salary for year 1 and 2 for S. Ramaswamy , including University of Minnesota Indirect cost recovery at 52%	$ 6,775	*secured*
in kind, 1**%** salary for year 1 and 2 for U. Tschirner , including University of Minnesota Indirect cost recovery at 52%	$ 4,289	*secured*
total in kind $ 114,690		
Remaining $ from Current ENRTF Appropriation (if applicable):	N/A	*N/A*
Funding History: funding for preliminary study was provided byt IREE (Initiative for renewable energy and the environment. This project helped establish general parameters	$ 220,000	completed 2012



Current process



NEW PROPOSED PROCESS

Potential for increased utilization of forest biomass, increased carbon sequestration, cleaner air, reduced use of petroleum.

Project Manager Qualifications and Organization Description

Dr. Tschirner as PI will be responsible to lead the project and the overall management of the research including meeting and objectives and deliverables, following the timeline and keeping track of progress, facilitate exchange of research information, and preparation and submission of progress reports and the final report. Dr. Tschirner has a strong background in biomass conversion, including a Ph.D. in lignin chemistry and nine years of industry experience in pulping and bleaching (Scott Paper Company). She has been a faculty at the University of Minnesota since 1995. Some of her recent research activities include projects focused on development of biomass pretreatment methods and biocatalytic conversion of cellulose to bioethanol as well as projects considering anaerobic digestion of biomass, mainly Municipal Solid Waste (MSW) for biogas generation. Dr. Tschirner will be responsible for the development and optimization of the hemicellulose pre-extraction process and the subsequent pulping, papermaking and fiber properties evaluation. In addition she will be responsible for the study focusses on hemicellulose application options, determining potential replacement of petroleum based fuels, chemical and materials through hemicellulose. These activities will be performed by a research associate in the first 15 months of the project.

Dr. Ramswamy, Department of Bioproducts and Biosystems Engineering, University of Minnesota, holds degrees in Chemical Engineering and Paper Science and Engineering and has relevant industry experience as Research Engineer in paper and chemical industry (Scott Paper Company and Hercules Inc.). Dr. Ramaswamy joined the University of Minnesota in 1995. He will be responsible for the membrane separation process development, as well as the process modeling, simulation and engineering analysis of the integrated biorefinery. He will be using experimental findings as well as literature data and data provided by paper mills as inputs to develop the process model and techno-economic analysis. In addition, he will also perform the environmental assessment of the proposed system including carbon balance implications and greenhouse gas emission reduction. This work will be performed by one full time post-doctoral research associate in year two.

At the Department of Bioproducts and Biosystems Engineering (University of Minnesota) several standard laboratory facilities and pilot plant facilities geared towards thermo chemical processing and characterization of lignocellulosic material are available in Kaufert Lab and will be used for raw material preparation, hemicellulose pre-extraction, pulping, bleaching, biomass characterization, paper making, and paper property evaluations. Ramaswamy's group has the necessary computer modeling capabilities and associated software. In addition the PIs have access to large number of sophisticated analytical and characterization services at the University of Minnesota Twin Cities campus.