Environment and Natural Resources Trust Fund
2010 Request for Proposals (RFP)

LCCMR ID: 054-B1

Project Title:

Non-Food Based Biofuels to Augment Corn Ethanol

LCCMR 2010 Funding Priority:

B. Renewable Energy Related to Climate Change

Total Project Budget: $ $379,117

Proposed Project Time Period for the Funding Requested: 3 years, 2010 - 2013

Other Non-State Funds: $ $0

Summary:

To provide an economic non-food based raw material source for existing or new ethanol plants we propose to recover hemicellulose(currently burned) and waste fiber (currently landfilled) from papermills.

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Sponsoring Organization: U of MN

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Location:

Region: Statewide

County Name: Statewide

City / Township:

_____ Knowledge Base _____ Broad App. _____ Innovation

_____ Leverage _____ Outcomes

_____ Partnerships _____ Urgency _____ TOTAL

MAIN PROPOSAL

PROJECT TITLE: *NON-FOOD BASED BIOFUELS TO AUGMENT CORN ETHANOL*

PROJECT STATEMENT

We will be reaching the maximum mandated limit of 15 billion gallons of corn based ethanol in the very near future. In addition, the exploitation of a food source for fuel is continuously being questioned. Obviously, the need for developing a non-food based biofuels is imminent. We are proposing the use of a non-food resource (wood) to augment corn based ethanol in Minnesota and nationwide. Specifically, we are proposing to add one process step to existing pulp mills to recover hemicellulose, a wood based sugar that is currently being burnt, and convert this material into ethanol or other biofuels.

Currently approximately 5,000 tons of dry pulp wood is processed to papermaking fiber in Minnesota, using the Kraft pulping process alone. Wood consists of three main components, cellulose, hemicellulose and lignin. In the process of producing papermaking fiber (mainly cellulose) hemicelluloses and lignin are dissolved in the so called black liquor. To prevent environmental impact and recover energy and chemicals, black liquor is concentrated and burned. As the heating value of hemicelluloses is very low combustion is not an effective use of these sugar components. Instead of burning, we are proposing to extract the hemicelluloses from the wood chips before the pulping stage for generation of biofuels such as ethanol. The hemicellulose can be concentrated and shipped to existing corn based ethanol plants or used as raw material for potential new (entirely wood sugar based) ethanol plants. Similar to corn based ethanol, hemicellulose is converted to ethanol through a fermentation process. Another source of fermentable sugars to be found in pulp mills is mill sludge, the solid material removed from effluent treatment plants currently discarded to landfills. This mill sludge contains large amounts of fines (very short cellulose fibers), potentially another excellent source of sugars for biofuels generation.

The overall goal of this project is to develop a biorefinery, producing bioenergy and papermaking fiber at the same time. By co-recovering hemicellulosic sugars and cellulose from mill sludge for ethanol production and long fiber cellulose for paper, we will maximize the value of the end products and thereby improve the economics of paper and ethanol production from wood. A detailed process model based on technical, economic and environmental considerations will allow us to optimize the process and products. This work is expected to have an impact throughout the state and across the nation, where there are existing forest based or ethanol industries. Bioenergy from trees clearly impacts greenhouse gases as they can be carbon neutral or carbon negative, absorbing atmospheric CO_2 fixing carbon through their extensive root system, which remains in the soil even as the trees are harvested and removed.

Our approach involves (1) pre-extraction of hemicelluloses prior to pulping (2) maintaining the same yield of high quality cellulosic fibers for subsequent paper manufacturing, (3) concentration and biocatalytic conversion processes for hemicellulose and fines recovered from mill sludge to ethanol, (4) effective recovery/recycling of chemicals and (5) development of a computer model based on information collected in 1-4 .

II. DESCRIPTION OF PROJECT RESULTS

Result 1: **Lab based pre-extraction and pulping study** **Budget:** $ 208,437

We will be using a pre-extraction process developed in our lab to remove hemicellulose from wood chips. Pre-extracted chips will then be converted to pulp fiber for papermaking. A new membrane filtration process will be developed to concentrate the hemicellulose for fermentation either on site (ethanol plant at pulp mill) or at existing corn based ethanol plant.

Deliverable	Completion Date
1. *Optimization pre-extraction of hemicellulose (high sugar yield)*	*06/12*
2. *Membrane filtration of hemicellulose (low cost, high yield)*	*06/12*
3. *Optimize pulping of remaining chips (high pulp yield, low cooking times, temperatures and chemical use)*	*12/12*
4. *Paper testing to demonstrate preservation of high fiber quality*	*06/13*

Result 2: Fermentation of wood based sugars to ethanol **Budget:** $ 58,000

We will perform lab scale fermentation processes to optimize fermentation of hemicellulose (C5 and C6 sugars) with and without addition of mill fines (sludge) to ethanol.

Deliverable	Completion Date
1. Determine and if necessary remove fermentation inhibitors	*06/11*
2. Lab scale fermentation study to convert hemicellulose	*06/12*
3. Co-conversion of fines and hemicellulose to ethanol	*06/13*

Result 3: Process model **Budget : $** 112,680

Development of a computer model based on information collected in Lab studies and in pulp mill.

1. Development of detailed process model for the hemicellulose extraction, separation and purification and further bioconversion	*06/12*
2. Integration of these steps with an existing pulp and paper operation using a combination of WinGEMS and Aspen Plus	*12/12*
3. Evaluate the technical and economic feasibility and optimization of the overall integrated biorefinery.	*06/13*

III. PROJECT STRATEGY

A. Project Team/Partners

Overall project management, including submission of interim reports, compiling of data 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, a 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. She will be assisted by Dr. Martinez, an experienced Research Scientist with a strong background in biotechnology. 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 assembly of the process model. We will be assisted by ADM, a major biofuels producer and technology leader and by our paper industry collaborator (Mike Schultz, SAPPI fine paper).

B. Timeline Requirements

We are proposing a 3 year project. Year one and two will be used to optimize the hemicellulose pre-extraction and membrane concentration processes, as well as the fermentation of hemicellulose and fines to ethanol. The process model work will start year 2 and will use data collected in the lab studies as well as mill data (existing pulp mills and existing ethanol plants).

C. Long-Term Strategy

The next step for this project will be scale up to pilot plant size followed by implementation in an existing pulp mill and existing ethanol plant, these steps will have to be financed by these industries. We will work closely with local paper mills (SAPPI), biofuels producers (ADM) and ethanol plants to make technology transfer as seamless as possible.

Project Budget

IV. TOTAL PROJECT REQUEST BUDGET (3 years)

BUDGET ITEM	AMOUNT
Personnel:	$ -
PI Tschirner - 1 month summer salary years 1-3; fringe benefits at 32.3%, Tschirner is on a 9 months appointment. Responsibilities: ***Project management, hemicellulose pre-extraction, pulping processes, analytical procedures***	$ 54,102
100% time post-doc years 2 and 3; fringe benefits at 19.75% Responsibilities***: Development of process model***	$ 105,680
50% Graduate Research Assistant years 1-3; fringe benefits - 25% during summer; 16.84% health care plus $14.32 tuition per hour worked; ***Co-supervised by Tschirner/Ramaswamy, hemicellulose extraction, filtration, pulping and papermaking***	$ 115,028
3 months per year Blanca Martinez (research scientist) salary, years 1-3; fringe benefits 37% *Responsibilities:* ***Perform all experiments related to fermentation of sugars to ethanol,***	$ 61,307
Equipment/Tools/Supplies:	$ -
Filtration Unit; ***to be used to concentrate hemicellulose before fermentation. This is a piece of equipment very specific to this project, it is needed to generate larger amounts of sugar for subsequent fermentation to ethanol.***	$ 20,000
Software license; ***($2,000/year). The software (ASPEN Plus and WinGEMs) is essential for the process modeling part of this project, the software will not be purchased, but licensed for use specifically for this project.***	$ 6,000
Laboratory supplies; ***chemicals and small scale lab supplies for 3 years; including enzymes for hydrolysis, chemicals for pre-extraction, columns for analytical procedures, beakers and other glassware, etc.***	$ 15,000
Travel:	
Instate Travel; ***Travel to Minnesota paper mills to collecting of chips, meetings with ethanol plant and paper mill personal, collecting of process data for model***	$ 2,000
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$ 379,117

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: *commercial wood chips, industry partners time, travel participants, in kind, time for Co-PI Ramaswamy*		
Remaining $ from Current Trust Fund Appropriation (if applicable): *Specify $*	N/A	*N/A*
Funding History: *funding was provided by the Initiative for renewable energy and the environment (IREE) to explore different hemicellulose pre-extraction processes. The alkali process developed in the IREE study will be used for this proposal.*	$ 220,000	project completed June 08

Project Manager Qualifications and Organization Description

Dr. Tschirner as PI will be responsible to lead the project and facilitate exchange of research information, keep track of progress, and compile 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. Her most recent research activities include projects focussed 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 and testing of paper properties. These activities will be performed by a graduate students (PhD) co-advised by Tschirner and Ramaswamy.

Fermentation of hemicellulose and fines to ethanol will be studies by Dr. Martinez (Department of Bioproducts and Biosystems Engineering, University of Minnesota). Dr. Martinez is an experienced Research Scientist with a Ph.D in Medicinal Chemistry and Pharmacognosy and a very strong background in biotechnology. Some of her most relevant reseach projects include studiesfocused on increasing fermentation yield of Butanol from *Clostridium acetobutylicum or* polyhydroxybutirate from *Alcaligenes euthrophus*.

Dr. Ramswamy, Department of Bioproducts and Biosystems engineering (University of Minnesota) holds graduate degrees in Chemical Engineering and Paper Science and Engineering and has relevant industry experience as Research Engineering in paper 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 generated by Tschirner and Martinez as well as literature data and data provided by paper mills as inputs to develop the process model. The modeling work will be performed by one full time post-doctoral research associate in years two and three.

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 assigned to the PIs (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 testing services and analytical equipment at other locations at the University of Minnesota Twin Cities campus

Examples of relevant recent publications of PI and Co-PI

*Al-Dajani, W**., Tschirner**, U. Pre-extraction of hemicelluloses and subsequent Kraft pulping. Part I. Alkaline Extraction, TAPPI Journal (2008) 7 (6) pp 3-8*

*Hua-Jiang Huang, Shri **Ramaswam**y, R.A. Cairncross, U. W. **Tschirner** and B.V. Ramarao; A review of separation technologies in current and future biorefineries, Separations and Purification Technology (2008) 62(1) pp 1-21*

*Hua-Jiang Huang, Shri **Ramaswamy**, W. Al-Dajani, W., U. W. **Tschirner**, R.A. Cairncross, "Effect of biomass species and plant size on cellulosic ethanol: A comparative process and economic analysis", Biomass and Bioenergy (2008), (available on-line) doi:10.1016/j.biombioe.2008.05.007*

*Hua-Jiang Huang, Shri **Ramaswamy**, R.A. U. W. Tschirner and B.V. Ramarao, Separations and Purification during bioalcohol production, Chapter in "Bioalcohol production: Biochemical conversion of lignocellulosic biomass", Editor: Professor Keith Waldron, Institute of Food Research, Norwich, UK, Woodhead Publishing, U.K.*