NDSU NORTH DAKOTA STATE UNIVERSITY

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January 30, 2008

North Dakota Industrial Council
600 E. Boulevard Ave. Dept. 405
Bismarck, ND 58505

RE: Project Title: Developing a Biomass Industry in North Dakota
PI: Dr. F. Larry Leistritz

Dear North Dakota Industrial Council:

A proposal for the above referenced project in the amount of $800,000 is hereby submitted on behalf of Dr. F. Larry Leistritz.

Please accept this transmittal letter as a binding commitment on behalf of North Dakota State University to complete the project as described in the attached application should this project be selected for funding.

The proposal has been administratively approved by North Dakota State University. Questions should be directed to Amy Scott at 701.231.8045, or email ndsu.research@ndsu.edu.

Sincerely,

Amy B. Scott

Amy B. Scott
Assistant Director
Office of Sponsored Programs
North Dakota State University

Project Title: Developing a Biomaterials Industry in North Dakota

Applicant: North Dakota Agricultural Experiment Station

Principal Investigator: F. Larry Leistritz

Date of Application: January 30, 2008

Amount Requested: $800,000

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Abstract

A consortium led by NDSU is currently engaged in a project to develop and commercialize technologies for producing cellulose nanofibers (very small fibers). The aim of the project is to develop and commercialize technologies to produce material and fuels from biomass feedstock in North Dakota. Wheat straw will be the initial feedstock. The technologies will be integrated in a multi-product biorefinery, which will produce ethanol and electricity as well as cellulose nanofibers for nanocomposite material. The next stage of the project is the completion of a front end engineering and design study addressing key engineering and economic questions to quantify the technical and economic feasibility of a pilot scale production process. These efforts will be supplemented with consultations and input from industrial energy experts from Great River Energy.

The proposed effort will be completed in one year for a cost of $800,000. The consortium is being led by the North Dakota Agricultural Experiment Station with Dr. F. Larry Leistritz serving as principal investigator. Amit Shukla from Great River Energy will serve as technical consultant to NDSU and MBI International. Donald M. Senechal (The Windmill Group, Drake, ND) will serve as a consultant to NDSU. MBI International is leading efforts in process and product development. Dr. Bernie Steele, Director of Operations will serve as Principal Investigator for MBI. Dr. Lawrence T. Drzal will direct work at the Michigan State University Composite Materials and Structures Center under a subcontract to MBI International.

Project Description

The economic potential of bio-based products (materials, fuels, chemicals) is substantial; the recent growth of the corn ethanol industry demonstrates that potential. However if biomass feedstocks are to expand their role in national markets, a broader resource base and corresponding processing technologies are clearly needed. Developing biomass-based energy and products is of particular interest in the Midwest and Great Plains. North Dakota is no exception as it has large potential supplies of agricultural biomass and is well positioned to be on the leading edge of the emerging bio-based economy.

A consortium led by NDSU is currently engaged in a project to develop and commercialize technology for producing cellulose nanofibers (very small fibers). The aim of the project is to produce materials and fuels from biomass feedstocks in North Dakota. Wheat straw will be the initial feedstock. Other locally produced raw materials (e.g. industrial hemp, switchgrass) represent other potential feedstocks. The technologies will be integrated in a multi-product biorefinery, which will produce ethanol and electricity as well as cellulose nanofibers for nanocomposite materials (Figure 1).

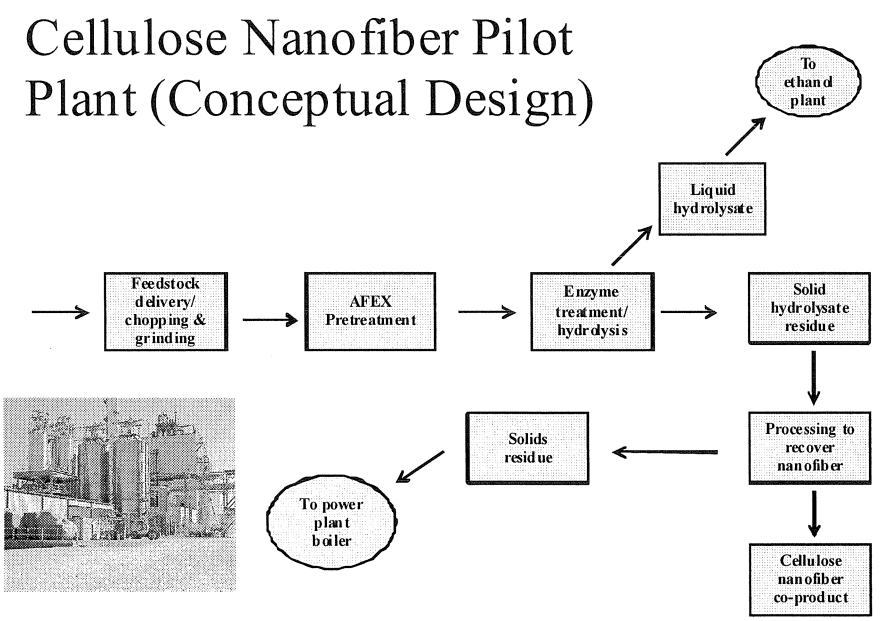

Figure 1.

Cellulose nanofibers (CNF) would be used to make biocomposites that could substitute for fiberglass and plastic in many applications, including automotive, furniture, office/storage, marine, housing and recreation. These bocomposites would be made from renewable sources, completely biodegradable, less toxic than fiberglass fibers, just a strong as fiberglass composite with half the weight, and cost less to produce.

The initial (*preliminary investigation*) phase of the biomaterials initiative has been completed with very encouraging results. The next stage of the project is the completion of the *detailed investigation* phase. During the *detailed investigation* stage, a front end engineering and design (FEED) study will be completed to address key engineering and economic questions to quantify the technical and economic feasibility of a pilot scale production process while at the same time analyzing the integration of components made from biomaterials into the supply chain. These analyses are prerequisite to the construction and operation of a pilot plant to demonstrate the commercial potential of this technology. These efforts will be supplemented with consultations and input from industrial energy experts from Great River Energy. Consultation with GRE staff will greatly enhance the scale up activities to be undertaken during the *detailed investigation* especially considering the potential for integrating a biorefinery with one of GRE's existing energy facilities (Figure 1, Appendix 1). In addition to design specifications for a pilot plant, a strategic business plan will also be completed as part of the FEED study during the *detailed investigation.*

Findings from the detailed investigation will provide technical and economic requirements for pilot plant construction which would be the initial step in the *development* phase. One or more business partners will be sought to move to this next stage in the

commercialization process. During the development phase large samples of cellulose nanofibers and nanocomposite materials would be produced and evaluated. Further, process definition, design, engineering, capital and operating costs for a commercial scale facility would be refined.

The intent of the work proposed here is to extend the current project by (1) completing the analysis necessary to define value propositions and (2) developing the strategic business plan for industry development needed to move the project from the investigation stage to the *development stage*.

Objectives

The goal of this project is to complete a front end engineering and design (FEED) study for a pilot scale plant to demonstrate the commercial potential of this technology, a critical step in establishing a biomaterials industry in North Dakota. Initial efforts will be focused on technical and economic requirements for commercializing technology to produce bio-based cellulose nanowhiskers. Specific objectives include:

1. Completing the detailed investigations necessary to define:

- scalable process design
- mass and energy balances necessary to determine the cost of the process
- a procedure for qualitative and quantitative analysis of the structural materials available from wheat straw
- a system for analyzing the structural enhancements of polymers from the inclusion of wheat straw fibers

2. Refining the initial Investment Analysis for the business as data is added to key parameters regarding capital costs and manufacturing yields.

3. Preparation of a strategic business plan for integration of public and private sector resources to provide investment for pilot plant construction and, when appropriate,

construction of commercial manufacturing facilities. The strategic business plan will detail the likely nature of operations for a corporate entity as well as examine potential markets, capitalization requirements, and projected financial performance.

Approach/Methods

Our approach assumes that cellulose nanofibers for production of biocomposite materials can be a value-added byproduct in a cellulose to ethanol biorefinery. Production of cellulosic ethanol from wheat straw is dependent on the effects of the Ammonia Fiber Expansion (AFEX) pretreatment process for conversion of cellulosic biomass to fermentable sugars. The AFEX process has been licensed to MBI for development and commercialization. The residual materials from ethanol fermentations contain cellulose nanofibers. Residual materials remaining after cellulose nanofiber extraction could be cofired into an electric generation station (Figure 1). During the project period the FEED study will address the following areas:

1. Detailed investigation of the AFEX process with regard to processing of wheat straw for conversion of cellulose/hemicellulose to ethanol. The program will seek to optimize the AFEX process for efficient conversion of wheat straw cellulose and hemicellulose to fermentable sugars for production of ethanol and define the mass balances. Key processes to be investigated are:

    - Verify the scalability of a continuous AFEX process design
    - AFEX processing conditions including temperature, pressure, ammonia loading and retention times
    - Enzyme hydrolysis conditions including screening of enzymes for more efficient conversion
    - Screening of organisms capable of utilizing both 5 and 6 carbon sugars

2. Determine the best extraction methods for refining cellulose nanofibers from wheat straw fermentation residues. The project will:

- Define the process
- Determine the mass balances

3. Detailed investigation of the production of biocomposites from wheat straw nanofibers.

The program will investigate:

- Potential uses of enhanced polyvinyl alcohol (PVOH) films
- Expansion of resin use beyond PVOH
- Production of test bars for comparative analysis
- The production of waste streams and potential use/disposal of such streams
- Determination of mass balances for the process

4. Economic modeling. The project will:

- Update the current models with mass balances and current economic data
- Develop a preliminary pilot process design

5. The information developed in steps 1- 4 will be used to develop a strategic business plan that details the likely nature of operations and corporate organization for a commercial entity as well as examine potential markets, capitalization requirements, and projected financial performance. This business plan will be prepared so as to be readily usable by potential partners for investment analysis to facilitate the commercialization process. The study team will identify potential private sector investors who have a strategic interest in commercializing this technology (e.g., potential users of material, energy companies, engineering firms). Based on interaction with potential investors, the plan will be refined, with the goal of achieving commitment by investors and stakeholders that will provide for the long-term implementation of the plan, construction of a commercial biorefinery in North Dakota.

Project Team

This research and development project is being undertaken by a consortium led by the

North Dakota Agricultural Experiment Station, with Dr. F. Larry Leistritz, Professor, Department of Agribusiness & Applied Economics serving as principal investigator and Nancy M. Hodur, Research Scientist, co-principal investigator. Amit Shukla from Great River Energy will serve as an industry technical consultant to NDSU and MBI International. Donald M. Senechal (The Windmill Group, Drake, ND) will serve as a consultant to NDSU. MBI International will lead efforts in process and product development. Dr. Bernie Steele, Director of Operations will serve as Principal Investigator for MBI. Dr. Farzaneh Teymouri, Senior Engineer will direct the technical operations of MBI and its consultants. Dr. Lawrence T. Drzal will direct work at the Michigan State University Composite Materials and Structures Center under a subcontract to MBI International. All of these individuals bring unique qualifications and capabilities to the project team. Resumes are available on request.

Standards of Success

The aim of this project is to commercialize a biomaterials industry in North Dakota. Completion of this research is absolutely critical to those efforts. As a top ranking state in the availability of low cost biomass, North Dakota is uniquely positioned to become a key player in the emerging biobased economy. Completion of the current stage *(detailed investigation/FEED study)* of this project will provide potential investors the technical and economic information necessary to move forward and take the next critical step in the commercialization process, construction of a biomaterials pilot plant and ultimately a commercial scale plant.

Development of a commercial scale facility would make a major contribution to the North Dakota economy. Construction of a 50 million gallon per year (MGY) cellulosic ethanol refinery has been estimated to cost $176.5 million. Twenty-five percent of the project cost would

represent expenditures to North Dakota vendors and contractors. Annual project operating costs were estimated at $74.6 million, of which $53 million were estimated to be paid to North Dakota entities. The largest single operating cost was for the wheat straw feedstock, $36 million annually, all of which represents payments to local entities (i.e., farmers, custom balers, and truckers). The biorefinery would employ 86 workers, and the plant's expenditures would support at least 2,000 jobs in other sectors of the state economy. Several hundred of these would likely be associated with feedstock harvest and transportation. It can also be noted that the economic impact of operating a cellulosic ethanol biorefinery would be approximately three times as great as those associated with a corn ethanol plant of similar capacity.

By developing the technology to produce a valuable co-product (nanofibers) from what would otherwise be a low-value residue from the hydrolysis/fermentation process, the project has substantial potential to enhance the economic attractiveness of cellulosic biorefineries. Successful completion of the project will thus increase the probability of near-term development of North Dakota's biomass resources. The contributions of Great River Energy staff enhances the probability of the near-term development of a biomaterials industry in North Dakota through the potential for locating and integrating these technologies at one of their energy facilities.

Background/Qualifications

Key participants in this project are the North Dakota Agricultural Experiment Station (NDAES), MBI International, The Windmill Group, the Michigan State University Composite Materials and Structures Center, and Great River Energy. The NDAES has an extensive history of research on priority issues affecting North Dakota agriculture. MBI International is a critical partner with an extensive history of commercializing biotechnologies. Founded in 1981 MBI

International has built a successful track record of innovation in industrial biotechnology, and has commercialized a number of products and processes. For example, MBI's joint venture with Cargill led to the launch of Natureworks, a manufacturer of polylactic acid, a corn based biodegradable substitute for petroleum based fibers and containers. Another MBI project led to the development of a critical component of the cholesterol-lowering drug Crestor. The Windmill Group and its founding principal, Donald Senechal, have been involved in the launch of a number of successful agricultural processing ventures in North Dakota, including Dakota Growers Pasta, Avico/Cavendish Farms, and ProGold. The MSU Composite Materials and Structures Center is internationally known for its work in research and engineering of polymers and polymer composite materials. Great River Energy is a leader in identifying and using renewable energy sources.

Management

The key project participants have been working together in efforts leading to the present undertaking for the past three years. In this context, the project team has established a management system featuring (1) regular (generally at least weekly) e-mail communications, (2) periodic (at least quarterly) reviews of progress, and (3) publication of research findings and outreach efforts upon completion of key milestones.

Timetable

The project will be conducted over a 12 month period with an interim report upon request in the form of a presentation to the Renewable Energy Council and/or the Industrial Commission on activities and findings to date 6 months after work begins.

Activity:	Study Months: 1 3 6 9 12
Scalable Process Design	
Enzyme/organism studies	
Mass Energy Balances	
Analysis of Structural Materials	
Quantitative Analysis of Mechanical Properties	
Strategic Plan/Investment Analysis	
Stakeholder interactions	

Budget

The cost to complete the detailed investigation phase of the project is $800,000. The NDSU Department of Agribusiness & Applied Economics proposes a fixed-price agreement with one-half payable at the time the project is initiated, one-fourth upon delivery of the interim report, and one-fourth payable upon completion of the final report.

NDSU Agribusiness & Applied Economics	$300,000
Principal investigator (summer salary, 2 mo.)(e.b. = 18%)	26,500
Research scientist/co-PI (10 mo.)(e.b. = 24.6%)	50,000
Research assistant (s)(8 mo.)(e.b. = 10%)	40,241
Employee benefits	21,131
Travel	11,500
Communication & supplies	628
Consulting services (The Windmill Group) ($135,000 professional services [211 days @ $640] plus $15,000 expenses)	150,000
MBI International (subcontract)	$500,000
Personnel (salary & benefits)	347,530
Materials & supplies	25,000
Equipment	45,000
Travel	12,470
MSU subcontract	70,000
Total cost	$800,000

Substantial other resources have been committed to this project. MBI International has invested over $8 million in the development of the AFEX technology. Further, MBI expects to leverage an additional $678,000 dollars during the course of this project through funding by the Department of Energy ($250,000), the UDSA ARS ($278,000), and internal commitments from MBI ($150,000). Great River Energy has committed to support the project through an in-kind contribution of staff time for consulting to facilitate the integration of a pilot scale production facility with one of their energy facilities. This contribution of staff time and associated costs (e.g., travel costs) is valued at $25,000.

To date, the U.S. Department of Agriculture, Cooperative State Research, Extension, and Education Service (USDA-CSREES) has supported the effort through three special grants totaling $494,638. The North Dakota Agricultural Products Utilization Commission (ND-APUC) has supported the effort with two grants totaling $86,100. Other project costs have been covered from internal resources committed by NDSU and MBI.

Patents and Rights to Technical Data

MBI International and MSU would retain all patents and rights to their respective technical data.

Appendix 1: Letter of Support and Cooperation

GREAT RIVER
ENERGY

17845 East Highway 10 • P.O. Box 800 • Elk River, Minnesota 55330-0800 • 763-441-3121 • Fax 763-241-2366

January 24, 2008

Dr. F. Larry Leistritz
North Dakota State University
Department of Agribusiness and Applied Economics
PO Box 5636
Fargo, ND 58105-5636

Subject: Support of Your Research Proposal / Offer of Participation

Dear Dr. Leistritz:

Thank you for the recent briefing on your work with cellulosic feedstocks and the research being pursued by your team. We believe your concepts and work scope have high potential value for North Dakota and the region and merit support.

From a GRE viewpoint, we are looking to the day when cellulosic process technology evolves and becomes economic. The potential of adding a secondary revenue stream for cellulose nanofibers could swing cellulosic ethanol plant economics, positive, sooner. We see the potential for locating and integrating your concepts at Spiritwood, Blue Flint, or other energy facilities. With that integration, the byproduct fiber (biomass) from such a cellulosic plant could be cofired into an electric generation station. The addition of biomass in our plant would offset fossil fuels with the evident benefit from a greenhouse gas standpoint. With the success of cellulosic technology, North Dakota, the region, and the U.S. add another production option for ethanol, diversifying from only corn based processes, and contributing further to domestic energy independence.

It is for these reasons we are supportive of your work and moreover would offer staff participation during your next phase. GRE staff expert in industrial energy processes will be made available to your team for consultation, especially important in your next phase as you consider the practicalities of scale-up to commercial concepts. We propose that contribution of up to 250 hours, including bearing in-kind expenses like travel to project meetings to have a value of $25,000.

As a member of North Dakota and the region's energy economy, we appreciate your team's effort and wish you the best.

Sincerely,

GREAT RIVER ENERGY

Gregory L. Ridderbusch
Vice President, Business Development and Strategy

Tax Liability/Tax Affidavit

NDSU NORTH DAKOTA STATE UNIVERSITY

Accounting Office – Division of Finance and Administration
P.O. Box 5227
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Fax 701.231.6194
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November 27, 2007

To whom it may concern,

North Dakota State University regularly pays taxes to the State of North Dakota for state income tax withholding, state sales taxes collected, and unrelated business income taxes. To the best of my knowledge, North Dakota State University is current and paid up on all tax liabilities with the State, with no past due balances.

Sincerely,

Gary Wawers

Gary Wawers
Controller