NDSU NORTH DAKOTA STATE UNIVERSITY

Office of Sponsored Programs Administration
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

701.231.8045
Fax 701.231.8098
ndsu.research@ndsu.edu

August 31, 2010

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 $406,120 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, PhD

Co-Principal Investigator: Nancy M. Hodur, PhD

Date of Application: September 1, 2010

Amount Requested: $406,120

Table of Contents

Page

DEVELOPING A BIOMATERIALS INDUSTRY IN NORTH DAKOTA

Abstract

MBI has developed a novel design to perform alkali pretreatment of biomass, using ammonia as a catalyst, that is anticipated to have much lower capital and operating costs over pervious Ammonia Fiber Expansion (AFEX) treatment processes. This process captures the ammonia on a new "packed bed" of biomass thereby avoiding the need for ammonia recovery and storage required in previous AFEX systems. This new treatment process has been demonstrated at bench scale (50 gram) and is called PB-AFEX.

This project is to scale up the PB-AFEX process to a three reactor semi-continuous system that operates at 4.5 kg per cycle. With data from operating this system we will be able to design a pilot scale system operating at one ton per day. The objectives of this project are to:

1. Design and build a three reactor continuous PB-AFEX laboratory system
2. Operate the reactor system to collect mass and energy balances necessary to design a pilot plant for the process
3. Use the PB-AFEX reactor to generate sufficient quantities of AFEX-treated material for applications testing of fermentation products systems and initial animal feeding trials
4. Develop a pilot scale plan including a) Process Flow diagram; b) Proforma of anticipated capital and operating costs; and c) Plan for product development
5. Develop a proforma for regional biomass processing centers using the PB-AFEX reactor and determine rural development implications for the project.

The project will be completed in 15 months. Total budget will be $812,120 with $406,120 requested from the Renewable Energy Development Program. Dr. F. Larry Leistritz, Professor, Dept. Agribusiness and Applied Economics, NDSU will serve as Principal Investigator. Dr. Bernie Steele, Director of Operations will serve as Principal Investigator for MBI, International. Dr. Farzaneh Teymouri, Senior Engineer, and Tim Campbell, Process Development Engineer, will direct the technical operations of MBI. Sandra Broekema of Great River Energy will serve as industry technical consultant.

Objectives

The goal of this project is to complete efforts to design a pilot scale plant for conversion of wheat straw to various biomaterials (i.e. fuels, chemicals, animal feed, etc). Specific objectives for this project include:

1. Prototype testing of a new AFEX reactor design that is less capital intensive
2. Prototype testing of this system for continuous ammonia reuse
3. Updating the commercial business plan to address a) Deployment on a regional basis; b) More flexible by-product potential; c) Updating the techno-economic analysis with a focus on regional biomass processing and rural development; and d) updating the economic requirements for construction of a pilot scale plant

Methodology

MBI has developed a new process for performing alkali pretreatment on wheat straw and other biomass materials. This new process is less capital intensive than previous processes and resolves the ammonia recovery and storage issue by storing the ammonia used in the process on beds of untreated biomass. The catalyst, ammonia, moves from one reactor to a second reactor eliminating the need to recover and store the ammonia for reuse. This process has been demonstrated at laboratory scale (50 gram batch). The availability of sugars from biomass after hydrolysis, using this new process is comparable with the conventional AFEX treatment processes. This novel process is called Packed Bed AFEX (PB-AFEX) and we have filed a patent application for the process.

Additional detail regarding research methodology are confidential and are available in the confidential portion of this application.

Anticipated Results

This lab scale reactor will allow us to determine the mass and energy balances necessary to develop an accurate plan for a pilot scale reactor. We also anticipate that a plan for loading and

unloading the reactors will be a part of the plans for a pilot plant reactor. It is expected that the techno-economic analysis will show a significantly reduced capital investment requirement for a commercial plant and will demonstrate the ammonia reuse at a scale attractive to potential investment partners.

Facilities

The lab scale reactor will be erected within the existing MBI facility. No new facilities are anticipated. Technology development at MBI takes place in a 120,000 square-foot, state-of-the-art R&D center, including a 20,000 square-foot pilot plant. The fully equipped facility is capable of supporting multiple projects in microbiology, molecular biology, bioprocess engineering, and materials science, and is well suited to conduct laboratory and pilot-scale research, development, and production. In addition to the laboratories and pilot plant, support services and administrative services are integrated into the facility, to efficiently coordinate project development.

Resources

This 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 Dr. Nancy Hodur, Assistant Research Professor, co-principal investigator. Sandra Broekema from Great River Energy will serve as industry technical consultant to NDSU and MBI International. MBI International will lead efforts in process and product development. Dr. Bernie Steele, Director of Operations will serve as Program Director for MBI. Dr. Farzaneh Teymouri, Senior Engineer, and Tim Campbell, Process Development Engineer, will direct the technical operations of MBI. All of these individuals bring unique qualifications and capabilities to the project team. Resumes are available on request.

Techniques to be Used, Their Availability and Capability

MBI is experienced in design and construction of prototype equipment for biomass processing and has access to the appropriate fabrication equipment at the MBI facility. The technologies and

equipment for hydrolysis and fermentation to develop products from the biomass sugars are also available at MBI. The objective is to develop product streams that can be extracted from the biomass prior to the fermentation residues being co-fired for electrical energy production.

The Packed-Bed AFEX (PB-AFEX) reactor concept has been demonstrated at bench scale using small (50 gram dry biomass) beds of wheat straw and corn stover. Based on these results, it is expected that the PB-AFEX reactor concept can be scaled up to produce the multi-ton quantities of treated biomass needed for animal feed trials, pelleting, pilot-scale fermentation, and other application tests. The overall goal of this project will be to accelerate the PB-AFEX approach from bench- to pilot-scale as quickly and as inexpensively as possible.

Tasks

1. Design, build, test – Scale up PB-AFEX from current bench scale (50 gram bed size) single reactor to three intermediate scale (about 1.5 kg bed size) reactors connected in series.
    1.1. Design calculations for 1.5 kg PB reactor system, based on results from 50 gram bench-scale experiments. Equipment will be specified based on the calculated mass flows and heat duties.
        1.1.1. Intermediate-scale PB reactor safety review – Review and revision of the design to identify and correct safety issues.
    1.2. Equipment and materials procurement
    1.3. Reactor assembly
    1.4. Ammonia recovery test cart assembly- The NH3 recovery test cart will include a compressor, water-cooled condenser, small pressure tank for liquid NH3 storage, and ancillary controls, on a mobile cart.
    1.5. Reactor System Shakedown - This task will include resolution of any problems that may be encountered regarding bed packing/unpacking, NH3 absorption/desorption, biomass

treatment, and some limited testing to determine effects of stover particle size, treatment time, temperature, NH3 loading, etc.

2. Reactor System Operations to produce sufficient materials for:
   2.1. Hydrolysis and fermentation studies
   2.2. Early animal feeding studies to determine palatability and energy values
3. Determination of mass and energy balances for Pilot Plant Design
4. Pilot-scale PB-AFEX Design To include:
   4.1. Process flow drawings
   4.2. Materials and equipment list
   4.3. Construction costs estimates
   4.4. Proforma for pilot plant and commercial plant operations
      4.4.1. Regional and/or centralized approach
      4.4.2. Detail the likely nature of operations
      4.4.3. Examine potential markets, capitalization requirements and projected financial performance
      4.4.4. Examine rural economic development implications and the economic impact of a commercial biomass conversion facility in North Dakota
5. Reporting – Appropriate interim and summary reports will be provided

MBI will design, fabricate and operate the processing equipment to demonstrate the production of ethanol from wheat straw. Great River Energy will collaborate with MBI on engineering and techno-economic analysis of the process. They will also provide characterization and analysis of fermentation residues to determine the applicability to co-firing for power/steam. NDSU with assistance from MBI will update the techno-economic analysis, the commercial business plan, and the likely nature of operations, including the potential economic impacts and rural economic development implications of regional

commercial biomass pre-pretreatment and conversion facilities. Findings will be used to facilitate the creation of a private sector and/or public private secure consortium to secure funding for the construction of a pilot scale facility with the ultimate goal of a commercial biomass pretreatment and conversion facility in North Dakota.

Environmental and Economic Impacts while Project is Underway

All necessary permits for biomass processing using ammonia are in place at MBI for this project. During the previous FEED study for the ND Industrial Commission a preliminary NEPA analysis was completed (see final report) and did not identify any significant environmental impacts for this type of project. The economic impact while the project is underway will be the direct employment of the personnel involved as shown in the budget.

Ultimate Technological and Economic Impacts

A primary objective is to lower the capital and operating costs for a cellulosic ethanol production facility in order to attract investment to build a commercial facility in North Dakota. The PB AFEX system is expected to offer significantly lower capital and operating costs than previously designed AFEX processing systems. The actual operating cost and the estimated capital cost for a pilot plant will be determined with information from the proposed three stage laboratory PB AFEX system. An additional objective is to improve the overall economics by utilizing biomass residues from biofuel production to generate power/steam.

Why Project is Needed

Electrical power generators in certain states are being required to produce a percentage of their power from renewable resources. The object of this project is to develop a practical method to extract sugars or materials from these resources prior to their use for co-fired electric power generation. Our partner, Great River Energy of North Dakota, has this need to improve the economic efficiency in co-

fired renewable energy sources in their generating plants. The overall objective is to be able to produce electrical power with a lower carbon footprint at the same or lower cost to the consumer.

The rural economic development potential of bio-based industry is substantial. Because of the bulk properties of potential feedstocks, including low bulk density and high yields of dust and fines during particle size reduction, there are major incentives for early stage processing to occur near the biomass source. Thus, the industry offers the prospect of not only an additional revenue stream for farmers (Coon and Leistritz 2006) but also new employment opportunities in rural areas of North Dakota and other agricultural states.

Standards of Success

The ultimate 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 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 that associated with a corn ethanol plant of similar capacity.

By developing the technology to produce a valuable co-product (biomass with significant Btu value) 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 enhance 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.

The success of a biobased economy has many potential advantages to the State of North Dakota and the public as a whole. Some of these are:

1. Lower carbon footprints for electrical generation
2. Reduced dependence on imported oil
3. Greater efficiency of biomass co-fired electrical generating plants through creation of additional product lines from sourced biomass materials
4. Rural economic development through biomass supply, biomass storage and processing and possibly localized biomass pretreatment

This project's focus is to develop a practical means of producing product streams from biomass that can directly benefit those required to co-fire biomass at electrical generation plants.

Background/Qualifications

In 2009 North Dakota State University, MBI and MSU conducted a Front End Engineering and Design Study (FEED) to develop a process for converting wheat straw to ethanol and other valuable co-

products. Prior to the completion of this study, the United States entered a major recession and the ethanol industry experienced increased difficulty in attracting the necessary financing to build new production facilities. The FEED study was based on the use of an ammonia-catalyzed pre-processing or pre-treatment step (Ammonia Fiber Expansion or AFEX) that renders the biomass more susceptible to enzymatic hydrolysis and fermentation to ethanol. MBI's original concept for continuous Ammonia Fiber Expansion (AFEX) treatment of biomass was based on wood delignification processes in the pulp and paper industry, using a Pandia-type reactor with feed and discharge screws. The operating principles of plug screws and Pandia reactors are largely independent of the fluid properties of the feedstock materials, so that the same equipment can be used to process materials with different properties, with only minor modifications. The primary disadvantage of this approach is the high capital and operating cost of the equipment required. This equipment requires large scale processing to achieve desirable economics of cost and operation. Due to the economic recession experienced during 2009-2010 the capital cost of this equipment has become an impediment to acceptance of the technology and subsequent acquisition of investment capital to build new facilities.

Key participants in this project are the North Dakota Agricultural Experiment Station (NDAES), MBI International, 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. Great River Energy is a leader in identifying and using renewable energy sources.

Project 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.

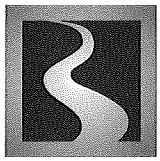
Budget

Project Expense	NDIC Share	Applicant Share	Applicant Share (in kind)	Other Project Sponsor's Share (in-kind)
NDSU				
Primary Investigator, 1 month	$14,255		$14,255	
PI-Employee Benefits	$2,566		$2,566	
Co-PI (6 months)	$34,160		$0	
Co-PI Employee Benefits	$9,642		$0	
Travel	$5,750		$0	
Indirect	$39,747		$7,317	
Subcontract	$300,000			
NDSU Total	$406,120		$24,138	
Great River Energy				
Personnel, travel, and internal lab analysis				$10,000
MBI Subcontract				
Personnel	$186,335	$66,445		
Benefits	$71,665	$25,555		
Materials	$32,000			
Travel	$10,000			
Indirect	$0	$279,982		
MBI Total	$300,000	$371,982		
Project Summary				
NDIC Share	$406,120	$371,982	$24,138	$10,000
Matching	$406,120			
Project Total	$812,240			

MBI, International has committed substantial additional resources in equipment and indirect costs to the project; however references to these additional resources are intended for informational purposes. NDSU does not intend these resources to be counted toward matching contribution requirements.

Timeline

		Month														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task	**Description**															
1	**Intermediate-scale PB reactor design, build, test**															
1.1	Design calculation for 1.5 kg PB reactor	→														
1.1.1	Intermediate-scale PB reactor safety review		→	→												
1.2	Equipment and materials procurement			→	→											
1.3	Reactor assembly				→	→										
1.4	Ammonia recovery test cart assembly				→											
1.5	Reactor system shakedown						→	→								
2	**Mass production of treated material**															
2.1	Hydrolysis and fermentation studies							→	→							
2.2	Early animal studies									→						
3	**Construct mass and energy balance**								→	→	→					
4	**Pilot-scale PB design**															
4.1	Develop process flow diagram						→	→								
4.2	Develop material and equipment list							→	→							
4.3	Estimate construction cost							→	→							
4.4	Proforma for pilot plant and commercial plant										→	→	→	→	→	→
4.4.1	Regional and/or centralized approach										→	→	→	→	→	→
4.4.2	Detail nature of operations										→	→	→	→	→	→
4.4.3	Projected financial performance										→	→	→	→	→	→
4.4.4	Economic development implications										→	→	→	→	→	→
5	**Reporting**										→	→	→	→	→	→



GREAT RIVER
ENERGY®

12300 Elm Creek Boulevard • Maple Grove, Minnesota 55369-4718 • 763-445-5000 • Fax 763-445-5050 • www.GreatRiverEnergy.com

June 7, 2010

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 that your concepts and work scope have high potential value for North Dakota and the region and merit support.

Great River Energy has a strong culture of innovation, and we see the potential benefits of using cellulosic biomass and by-products from cellulosic materials in power generation in order to reduce greenhouse gas emissions and advance U.S. energy independence and domestic security. In addition, there may be opportunities for integrating your concepts at one or more of our generation facilities.

We support your work and could offer up to $10,000 in-kind staff participation during your next phase. A GRE staff expert in utility energy processes could 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 a contribution of up to 40 hours, including direct out-of-pocket expenses such as travel and lodging for project meetings, and internal lab analysis of fermentation residues.

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

Sincerely,

GREAT RIVER ENERGY

Sandra Broekema
Manager, Business Development

Appendix B: Tax Liability/Tax Affidavit

NDSU NORTH DAKOTA STATE UNIVERSITY

Accounting Office – Division of Finance and Administration
NDSU Dept. 3100
P.O. Box 6050
Fargo, ND 58108-6050

701.231.7432
Fax 701.231.6194
www.ndsu.edu

August 23, 2010

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

F. (Fredrick) Larry Leistritz

BUSINESS ADDRESS: Dept. of Agribusiness & Applied Economics
North Dakota State University
Fargo, North Dakota 58105
(701) 231-7455 Phone
(701) 231-7400 FAX
E-mail: lleistri@ndsuext.nodak.edu

HOME ADDRESS: 138 49th Avenue E.
West Fargo, ND 58078
(701) 282-9129

PRESENT POSITION: Distinguished Professor of Agricultural Economics, North Dakota State University

EDUCATION:

Doctor of Philosophy: University of Nebraska, Lincoln, major in Agricultural Economics--August 1970

Master of Science: University of Nebraska, Lincoln, major in Agricultural Economics--1968.

Bachelor of Science: University of Nebraska, Lincoln, major in Agricultural Economics, degree with high distinction--1967.

SELECTED PROFESSIONAL ACTIVITIES:

International Association for Impact Assessment--President, 1993-94; Program Chair, 1991 Annual Conference; Director, 1985-88

Western Agricultural Economics Association--President, 1985-86; Director, WAEA Executive Council, 1981-83; Member of Editorial Council of *Western Journal of Agricultural Economics*, 1976-78 and 1982-85

HONORS AND AWARDS

Western Agricultural Economics Association, Distinguished Scholar of the WAEA, 2005

Business and Industrial Development Award, Greater North Dakota Association, 1998

NDSU Faculty Economic Development Award, 1995

Fargo Chamber of Commerce, NDSU Distinguished Professorship, 1994

Excellence in Research Award, Senior Faculty, North Dakota Agricultural Experiment Station, North Dakota State University, 1993

RESEARCH

Dr. Leistritz has authored more than 400 research publications, including more than 120 refereed journal articles and 12 books. He has directed grant and contract-funded research projects totaling more than $7.2 million.

Nancy M. (Wallace) Hodur, PhD
Department of Agribusiness and Applied Economics
P.O. Box 5636, NDSU
Fargo, ND 58105-5636
701-231-7357

Current Position:

Assistant Research Professor, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo (March 2001-present). Conduct research activities on a wide variety of subjects related to economic development, economic impacts, natural resources, and biomaterials. Research findings have been published in refereed academic journals, presented at national professional meetings and conferences, and delivered to numerous constituent groups in North Dakota. Special expertise in research methods, survey design and development and focus groups.

Education:

-- PhD, Natural Resources Management: North Dakota State University, Fargo, 2010
-- MS, Natural Resource Management: North Dakota State University, Fargo, 1991
-- BA, Business Administration: Jamestown College, Jamestown, ND, 1983

Publications (synopsis):

--	Principal author	7 articles in refereed journal
--	Co-author	7 articles in refereed journal
--	Principal author	12 papers or posters for proceedings at professional meetings
--	Co-author	7 papers or posters for proceedings at professional meetings
--	Principal author	14 research reports
--	Co-author	10 research reports

Selected Publications:

Leistritz, F. Larry, **Nancy M. Hodur**, Donald M. Senechal, Mark D. Stowers, Darold McCalla, and Chris M. Saffron. 2009. Use of Agricultural Residue Feedstock in North Dakota Biorefineries. *Journal of Agribusiness* Vol. 27, ½: 17-32.

Hodur, Nancy M. and F. Larry Leistritz. 2009. *Developing a Biomass Industry in North Dakota*. A report to the North Dakota Industrial Commission, Renewable Energy Council, Project # No. MB0-001-01, http://www.nd.gov/ndic/renew/projects/bm-001-001r1-10.pdf

F. Larry Leistritz, Dean A. Bangsund, **Nancy M. Hodur** and Donald M. Senechal. 2009. *Factors Affecting Agricultural Biomass Supply*. 2009. A report to Great River Energy as part of a study sponsored by the North Dakota Industrial Commission, Renewable Energy Council, Project # R-001-003, http://www.nd.gov/ndic/renew/projects/r-001-003fr.pdf

Leistritz, F. Larry, and **Nancy M. Hodur**. 2008. Biofuels: A Major Rural Economic Development Opportunity. *Biofuels, Bioproducts and Biorefining*, Vol. 2: 501-504.

D. Bernie Steele, PhD

Professional Experience:

1997-Present **MBI International**

Director of Operations: A senior manager with a background in microbial physiology and over 25 years of experience in biotechnology. Currently responsible for research & development operations including External Alliances, Intellectual Property Management, Quality Assurance and Laboratory Safety and serves as Biosafety Officer of MBI.

1996-1997 **Self-Employed, Consulting**

Provided professional consulting services in the area of microbial technologies. This included environmental projects, such as bioremediation, as well as microbial screening and discovery of novel microbial products, strain improvement, and microbial troubleshooting for industrial clients. Projects were conducted throughout North and Central America, Europe, and the former Soviet Union, for the U.S. Army Corps of Engineers and the Defense Special Weapons Agency. OSHA 29CFR 1910.120 40hr certification.

1993- 1995 **Harmon Environmental Services, Inc.**

Vice-President, Scientific Services: Responsible for research and development of biological systems technologies relating to bioremediation and wastewater treatment, and production of all biological products. Designed and implemented successful bioremediation projects for several major industrial clients as well as the U.S. Army Corps of Engineers in the United States and Central America. Coordinated all HES activities with Auburn University, and was responsible for a 5,000 gallon capacity fermentation and bioprocessing facility. OSHA 29CFR 1910.120 40hr certification.

1992 **Boeing Defense and Space Group**

Senior Research Scientist with Analytical Services in Boeing's Missile and Space Division. Responsiblities included methodology development for detection, enumeration and identification of microbes in the Advanced Environmental Control and Life Support System of Space Station Freedom. This included work on both recycled product water and in control of biofilms and biofouling of the water and air recovery systems. Bacterial, Fungal, and Viral challenge testing was designed and implemented by Dr. Steele. Methodology development included physiological studies, and molecular genetics (PCR) protocols for improved detection limits and rapid identification.

1988-1992 **Auburn University**

Manager of the Fermentation and Bioprocessing Unit in the University's Cell Science Center located in the Auburn University Research Park. Oversaw all fermentation work from 1 L to 250 L scale, including BL-2 fermentations and large scale recombinant fermentations. Research efforts centered on physiological adaptations to extreme environments and methods development for the screening of microorganisms for industrial use. Research efforts in the area of microbial screening have yielded several important discoveries of industrial enzymes

and biodegradative organisms. Such efforts have produced several patents and successes for major chemical companies.

1986-1988 **University of Tennessee/Oak Ridge National Laboratory**

Research efforts focused on microbial screening for industrial products, including industrial enzymes, and ice-biologicals. Additional research included environmental assessment and monitoring of cooling systems in nuclear reactors. This included biocide efficacy testing and evaluation as well as study of physiological mechanisms involved in microbial resistance to biocides. Research programs were initiated at the Institute with corporate clients such as Eastman Kodak BioProducts and government agencies such as the Tennessee Valley Authority. Several such successful collaborations resulted in long term research programs over several years.

1984-1986 **NPI**

Research Scientist: Involved in NPI effort to develop and produce nitrogen-fixing microbial inocula for forestry, horticultural and agricultural applications. This included the discovery and selection of superior symbiotic strains for large scale production of inocula. Projects involving the genetic manipulation of nitrogen fixing bacteria. Served as co-investigator on grants from the National Science Foundation and the US Agency for International Development. Responsible for all fermentation research and for implementation of a reforestation program in Nepal through USAID.

Educational Background

Dr. Steele received his B.S. from Auburn University (1980), M.S. (1984), and Ph.D. (1994)

Member of the American Society for Microbiology, and the Society for Industrial Microbiology.

Abstracts and Presentations

Steele, B., S. Raj, J. Nghiem, and M. Stowers. 2004. Enzyme Recovery and Recycle Following Hydrolysis of AFEX-Treated Corn Stover. 26th Symposium on Biotechnology for Fuels and Chemicals. Chattanooga, TN.

Steele, B., 2009. Preliminary Engineering and Design of a Cellulose to Ethanol Pilot Plant. Northern Plains Biomass Economy: What Makes Sense? Fargo, ND

Recent Publications

Steele, D.B., S. Raj, J. Nghiem, M. Stowers. 2005. Enzyme Recovery and Recycling Following Hydrolysis of Ammonia Fiber Explosion-Treated Corn Stover. Appl. Biochem. Biotechnol. 124: 901-910.

Duncan, M., I. Xiarchos, J. Whims, T. Scott, M. Stowers, D. Senechal, and B. Steele. *U.S. Biobased Products: Market Potential and Projections Through 2025.* U.S. Department of Agriculture OCE-2008-1. 2008. http://www.usda.gov/oce/reports/energy/index.htm

Farzaneh Teymouri, PhD

teymouri@mbi.org **(517) 337-3181 (office)**

Summary

8+ years experience in pretreatment and bioconversion of lignocellulosic biomass to value added products such as fuels and specialty chemicals. Extensive experience in ammonia fiber expansion (AFEX) pretreatment. Fairly familiar with the leading biomass pretreatment technologies such as dilute acid, steam explosion, hot water, ammonia percolation and lime treatment.

Education

Michigan State University East Lansing, MI
Doctor of Philosophy, Chemical Engineering, 2003

Sharif University of Technology Tehran, Iran
Bachelor of Science, Chemical Engineering, 1991

Experience

MBI **Lansing, MI**
Senior Scientist 2004 – present
Coordinating and Leading the lignocellulosic biomass pretreatment and processing research activities.
Specific accomplishments:

- Bench scale process development: Scaling up the AFEX process from 1 gallon to 5 gallon reactor.
- Defined operating parameters/conditions for AFEX pretreatment of several different biomass .
- Integrated AFEX with enzyme hydrolysis and fermentation steps.
- Developed methods to increase ethanol concentration in fermentation processes.
- Developed methods for selective hydrolysis of cellulose and hemicellulose portion of biomass and separation of C6 and C5.
- Development and testing of a continuous AFEX reactor system.

Michigan State University, Dept. of Chemical Engineering and Material Science **East Lansing, MI**
Research Associate (Postdoctoral) 2003 - 2004
Conducted research includes:

- Understanding factors that limit the enzymatic hydrolysis of biomass such as corn stover.
- Ammonia Fiber Explosion (AFEX) treatment of switchgrass and evaluating its digestibility via enzymatic hydrolysis and fermentation.
- Study inhibitory effect of xylose and its oligomers on cellulase activity.
- Modifying the AFEX treatment to use ammonium hydroxide as the pretreatment reagent and evaluating the results.

Publications

- **Teymouri, F**.; Laureano-Perez, L.; Alizadeh, H.; Dale, B. E.; "Optimization of the ammonia fiber explosion (AFEX) treatment parameters for enzymatic hydrolysis of corn stover" *Bioresource Technology* 96, 2014-2018, (2005).
- Alizadeh, H.; **Teymouri, F**.; Gilbert, T. I.; Dale, B. E.; "Pretreatment of switchgrass by ammonia fiber explosion (AFEX)" *Applied Biochemistry and Biotechnology* 121, 1133-1142, (2005).

- Laureano-Perez, L.; **Teymouri, F**.; Alizadeh, H.; Dale, B. E.; "Understanding factors that limit enzymatic hydrolysis of biomass" *Applied Biochemistry and Biotechnology* 121, 1081-1100, (2005).
- Hanchar R.; **Teymouri F**.; Nielson Ch.; McCalla D.; and Stowers D.; "Separation of Glucose and Pentose Sugars by Selective Enzyme Hydrolysis of AFEX-treated Corn Fiber" *Applied Biochemistry and Biotechnology* 136-140, 313-325, (2007).
- Bradshaw T., Alizadeh H., **Teymouri F**., Balan V., and Dale B., "AFEX and Enzymatic hydrolysis on two different stages of Reed Canarygrass" *Applied Biochemistry and Biotechnology* (In press).

Presentations

- **Teymouri F**.; Guettler M.; McCalla D.; Stowers M.; "Fed batch SSF of AFEX treated corn fiber, corn stover, bagasse and cane leaf matter (CLM)" AIChE Annual meeting Nov 1st 2005,Cincinnati, OH.
- **Teymouri F**.; Selig M.; Decker S.; Dale B.; "Hydrolysis of ground and unground AFEX treated corn stover with different combinations of cellulase and xylanase" 27th Symposium on Biotechnology for Fuels and Chemicals, Denver, Colorado, May 1-4, 2005.
- Tiedje T.; **Teymouri F**.; McCalla D.; Stowers M.; Chung C.; Day D.; Rein P.; **"**Separation of cellulose from hemicellulose and lignin from sugarcane bagasse and cane leaf matter" 27th Symposium on Biotechnology for Fuels and Chemicals, Denver, Colorado, May 1-4, 2005.
- **Teymouri F**.; Guettler M.; Saffron Ch.; Kleff S.; "Ethanol and Succinic Acid Production from AFEX treated Sugarcane Bagasse and Cane Leaf Matter (CLM)" 29th Symposium on Biotechnology for Fuels and Chemicals, Denver, Colorado, April 29th- May 2, 2007.
- Campbell T., Vu D., T**eymouri** F.; "Ammonia Phase Equilibrium in Vapor-Water-Biomass Pretreatment Systems" 30th Symposium on Biotechnology for Fuels and Chemicals, New Orleans, LA, May 4-7, 2008.
- Moore J., Kleff S., Headman Van Vleet J., Jeffries T., **Teymouri F.; "**Fermentation of biomass derived glucose/xylose mixture to ethanol using *Pichia stipitis*" 30th Symposium on Biotechnology for Fuels and Chemicals, New Orleans, LA, May 4-7, 2008.
- Campbell T., Vu D., T**eymouri F**.; "Ammonia Recovery in AFEX Biomass Treatment Systems" 31st Symposium on Biotechnology for Fuels and Chemicals, San Francisco, CA, May 3-6, 2009.
- Campbell T., T**eymouri F**., Senyk D., Glassbrook J., Nielson CH., Videto J.; "Development of a Continuous AFEX Process" 31st Symposium on Biotechnology for Fuels and Chemicals, San Francisco, CA, May 3-6, 2009.
- Rosentrater K., T**eymouri F**., Kalscheur K.; "Quantifying Livestock Feed Value of AFEX-Treated DDGS and Subsequent Biorefinery Byproducts" 31st Symposium on Biotechnology for Fuels and Chemicals, San Francisco, CA, May 3-6, 2009.

Synergistic Activities

- Design and execution of experiments to study AFEX process at bench scale.
- Design and execution of experiments to develop efficient methods for integration of AFEX process with hydrolysis and fermentation steps.
- Analyze lignocellulosic biomass structure.
- Participate in the CAFI (Consortium for applied fundamentals and innovation) study and currently serve as one of their advisory board members.
- Develop continuous AFEX process.
- Collaborate with other entities to evaluate the value of the by-product generated from fermentation of AFEX treated biomass.

Timothy J. Campbell

(517) 336-4631 (office)

campbell@mbi.org **(517) 242-3656 (cell)**

Summary

Chemical engineer with 20+ years experience in research and technology development. Expertise in reactor design, fuel chemistry and analysis, surface chemistry and catalyst development, and separation and purification processes.

Education

University of Florida — Gainesville, FL
Master of Engineering, Chemical Engineering, 1999

Northern Michigan University — Marquette, MI
Bachelor of Science, Biochemistry, 1983

Experience

MBI International — **Lansing, MI**

Process Development Engineer — 2007 – present

Development and de-risking of the Ammonia Fiber Expansion (AFEX) process for pretreatment of lignocellulosic biomass.

Specific accomplishments include:

- Studies of ammonia thermodynamics and transport in biomass systems.
- Development and testing of a continuous AFEX reactor system.

Applied Research Associates, Inc. — **Tyndall AFB, FL**

Research Chemical Engineer — 1994 - 2007

In support of Air Force Research Laboratory client, designed and executed experiments for a number of research projects. Specific projects included development of the Logistic Fuel Processor (LFP), a deployable reformer system for conversion of JP-8 to hydrogen for use with fuel cells, and investigation of chloro-organic groundwater contaminant reduction using zero-valent iron.

Specific accomplishments include:

- Design and testing of compact reactors, fuel fractionators, heat exchangers, and sulfur adsorption beds for the LFP system.
- Development of novel coated-wall catalysts for use in the LFP system, including cracking, steam reforming, and combustion catalysts.

University of Florida, Dept. of Civil Engineering — **Tyndall AFB, FL**

Research Chemical Engineer — 1999 - 2001

Lead researcher on a project to develop the Passive Flux Monitor (PFM), a novel device for in-situ monitoring of groundwater contaminant flux and specific discharge.

EnviroLab, Inc. **Ormond Beach, FL**

Chemist 1993 - 1994

Bench chemist performing routine analyses of water samples by HPLC, using EPA methods.

BioEnergy International, LLC **Gainesville, FL**

Research Asssistant 1992-1993

Performed bench-scale experiments on fermentation of cellulosic feedstocks to ethanol using novel genetically-modified microbes.

PCR, Inc. **Gainesville, FL**

Chemist 1989-1992

Analytical laboratory chemist for ISO-9000 certified specialty chemicals manufacturer.

Cuno, Inc. **Meriden, CT**

Research Assistant 1983 - 1988

Assistant in R&D laboratory of filtration and chromatography media manufacturer.

Publications and Patents

- Shaaban, A.H. and T.J. Campbell. Compact distillates fuel processor with effective sulfur removal process. U.S. Patent No. 7,318,845, January 15, 2008.
- Campbell, T.J., D.T. Vu, and F. Teymouri. Ammonia phase equilibrium in vapor-water-biomass pretreatment systems. Poster presentation at 30th Symposium on Biotechnology for Fuels and Chemicals, New Orleans, LA, May 4-7, 2008.
- Campbell, T.J., K. Hatfield, P.S.C. Rao, and M.D. Annable. Magnitude and Directional Measures of Water and Cr(VI) Fluxes by Passive Flux Meter. *Environ. Sci. and Technol*., **40**, 2006, p 6392-97. Selected "2006 Technology Paper of the Year" by the editors of *ES&T*.

Synergistic Activities

- Modification and operation of a continuous AFEX reactor system at MBI International.
- Design and execution of experiments to study ammonia/water equilibrium and transport in biomass pretreatment systems at MBI International.
- Design, fabrication, and testing of novel separations and purifications systems at ARA, Inc.
- Studied bench-scale conversion of cellulosic biomass to ethanol at BioEnergy International LLC.